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THE SCIENTIFIC MONTHLY

EDITED BY J. McKEEN CATTELL

CONTENTS

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THE SCIENTIFIC MONTHLY

OCTOBER, 1924

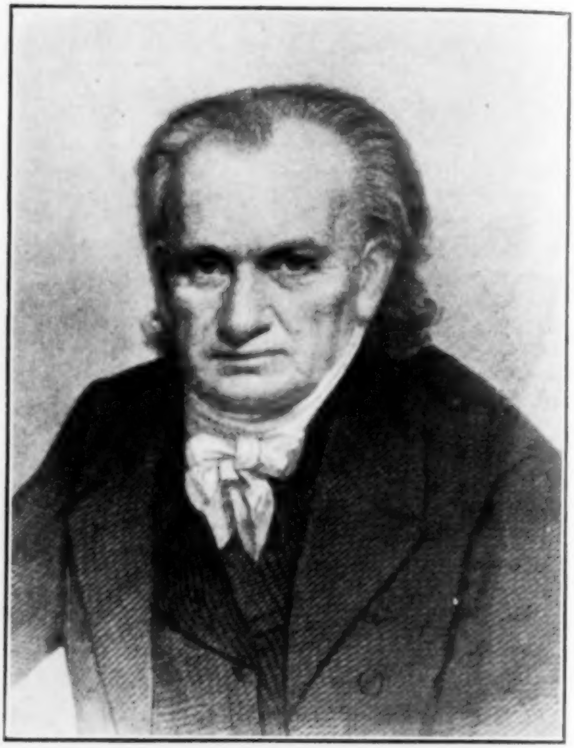
RENSSELAER POLYTECHNIC INSTITUTE AND THE BEGINNINGS OF SCIENCE IN THE UNITED STATES

By Professor RAY PALMER BAKER

RENSSELAER POLYTECHNIC INSTITUTE

During the first week in October, Rensselaer Polytechnic Institute celebrates the hundredth anniversary of its foundation. Since the school founded at Troy in 1824 by Stephen Van Rensselaer is the oldest institution devoted to science in any English-speaking country, and since its early courses related to both the farm and the factory, it was a pioneer in many fields; and it affected materially the development of many institutions.

In order to understand its influence during the first four decades of its history—a period in which a majority of the scientists in the republic were numbered among its graduates—it is necessary to know something at least concerning the man selected as its academic head. Amos Eaton was an original genius of profound and far-reaching intellect. Educated at Williams, the first of its alumni to achieve distinction, he studied at Yale under Benjamin Silliman, who lived to see his pupil transcend the barriers which had inhibited his labors in New Haven. Returning to Williamstown in 1817, he conducted a series of extracollegiate lectures on botany, geology and mineralogy which were attended by all the seniors and juniors and by all but four of the sophomores and freshmen. So popular were these lectures that the undergraduates of their own volition published the manuscript of the first group. Because of this success, Eaton determined to offer experimental courses wherever he could find an audience. As a result, over seven thousand students—in his day, an unprecedented number—attended his classes in natural history. In addition to those treated in this sketch, many of the most eminent scientists of the day—leaders like James Dwight Dana, professor of natural history in Yale University, Chester Dewey,



AMOS EATON

Amos Eaton (1776–1842). Senior Professor and Professor of Chemistry and Experimental Philosophy in Rensselaer Polytechnic Institute.

professor of chemistry in Rochester University, Asa Gray, professor of natural history in Harvard University, Albert Hopkins, professor of astronomy in Williams College, and John Torrey, professor of chemistry in Columbia University—began their work under his direction.

Now that it is possible to view his achievements in true perspective, it is clear that he is one of the great figures in the history of science in the United States. Though his botanical nomenclature has often been modified, the value of his researches has become increasingly apparent; and recent investigations by the United States Geological Survey have strengthened his position as the "father of American geology." Nevertheless, striking as were his discoveries and monographs, they were surpassed by his services to the cause of education. The first to introduce field work and laboratory practice into the American college, the founder, in Troy, of the first popular museum of natural history, a pathfinder in many fields, he illumi-

nated by his personality the city which he made his home. Devoted to the practical affairs of life, he still worshipped truth for its own sake; and it was this rare union of intellectual curiosity and rough-and-ready utilitarianism which made Rensselaer a center of "pure" scholarship—a development with which I am going to deal—as well as a school of agriculture and, after 1835, a college of technology.

Since he was a naturalist of the Old School, almost a "philosopher," in the Chaucerian sense, he ranged over many subjects—botany, zoology, physics, chemistry, geology and mineralogy; and in every field he fired the imagination of students who outreached him in knowledge and attainment. This statement is true of several of the biological sciences which to-day seem remote from the curricula of the institute. By 1828, Eaton had published treatises, manuals, exercises and dictionaries dealing with various aspects of botany. The eighth edition of his "North American Botany," issued in 1820, contains descriptions of 5,267 species. Under the circumstances, it is not surprising that many of the early graduates followed in his steps. Some of them paralleled his intellectual excursions with remarkable fidelity. James Hall ('32), of whose work at the University of Iowa I shall speak later, printed his "Catalogue of Plants Growing without Cultivation in the Vicinity of Troy, N. Y." in 1832, before he began his career as a geologist. Douglas Houghton ('29), who organized the Michigan State Geological Survey after the commonwealth had been admitted to the Union, acted as botanist on the first expedition to the source of the Mississippi. His able report on the flora of the Northwest can be traced to-day in the Houghton Herbarium at the University of Michigan. When he undertook the survey in 1837, he naturally surrounded himself with Rensselaer men, one of whom, Abram Sager ('31), now remembered by the Sager Herbarium, became chief of the botanical and zoological divisions. Sager, who, like several other graduates of the institute before 1850, luxuriated in every field from paleontology to obstetrics, laid the foundations of the departments of botany and zoology in the university. It is true that Asa Gray, who had also been inspired by Eaton, had been connected with it for a few months, but his connection was merely nominal. As in several of the other universities in the west, the pathfinders had been students in Troy.

Moreover, through his lectures, delivered at Amherst, Northampton and elsewhere, Eaton influenced a number of women who were to become conspicuous in the first half of the nineteenth century. "You can generally," he remarked, "persuade ladies to go out in small parties to the nearest open fields" and collect plants for the next day's study. And many evidently did go; for, in 1819,

Jane Welsh, who had been a member of his classes in Northampton—where he conducted the first courses in science ever opened to women—issued her "Botanical Catechism." Ten years afterward Almira Lincoln, a sister of Emma Willard, published her "Familiar Studies in Botany," a volume based upon Eaton's manuscripts. Finally, in 1840, Laura Johnson, who, like Mary Lyon, founder of Mount Holyoke College, had been a guest at his home and a student under him, put forth, under his supervision, the second edition of her "Botanical Teacher," a companion to the eighth edition of Eaton's "North American Botany." So far as I am aware, the movement culminating in this literature—a movement designed to "promote knowledge and magnify the Creator"—was the first of its kind on the continent.

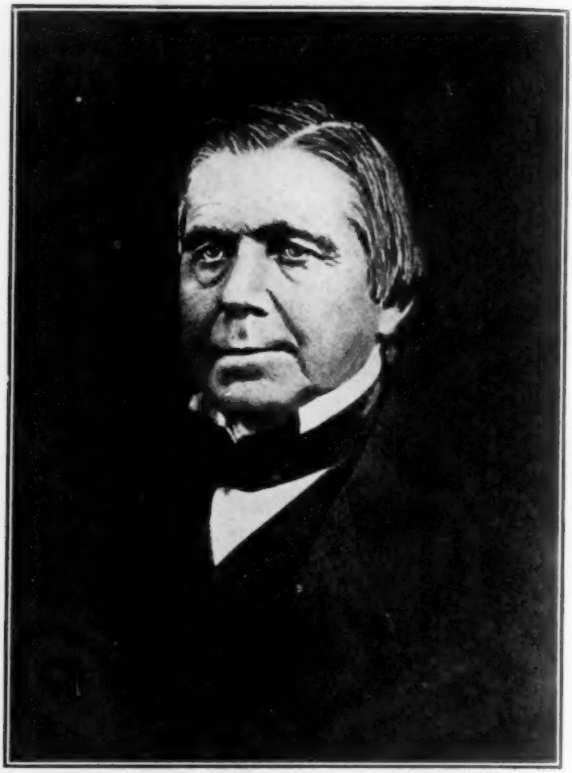
Though Eaton's "Zoological Syllabus and Note Book," published in 1822, emphasizes his interest in the biological sciences, the character of this interest is revealed more accurately by his "Geological and Agricultural Survey of the County of Albany, N. Y." (1820) and his "Geological and Agricultural Survey of the District Adjoining the Erie Canal" (1824). These volumes, reports of investigations which he had made through the patronage of Stephen Van Rensselaer, illustrate the practical side of his genius. They are interesting memorials of the first attempts to adapt the results of research to the needs of agriculture. When the history of education in the United States is finally written, it will be found, I think, that the institute was a powerful factor in shaping the agents which have ministered to its necessities.

In 1843, Ebenezer Emmons ('26), who lectured—as usual at the time—on geology, mineralogy and chemistry, in Albany, Rensselaer and Williams, and who, in 1836, became head of one of the four divisions of the New York State Geological Survey, was appointed chief of the agricultural section. In the next decade he issued four reports, the first dealing with the soils and rocks of the district; the second, with the grains and vegetables; the third, with the fruits; and the fourth, with the noxious organisms. From his monographs, which were illustrated—for the first time—by figures and plates, have sprung the bulletins of the United States Department of Agriculture. Even in the case of the bureaus associated with it, the institute was also a leader. In 1830, Eaton organized the first of his famous "expeditions" for the collection of plants, insects, rocks and fossils. On this excursion from New York to Lake Erie—an excursion which marked the beginning of serious field work in America—he was accompanied not only by Houghton, Emmons and Fay Edgerton ('28), whom I shall mention again, but also by Asa Fitch, Jr. ('27), who specialized in entomology.

EBENEZER EMMONS, '26

Ebenezer Emmons (1796–1863) Junior Professor in Rensselaer Polytechnic Institute. State Geologist of New York for the Second District. Professor of Geology and Mineralogy in Williams College. Chief of the Agricultural Department of the New York State Geological Survey. State Geologist of North Carolina.

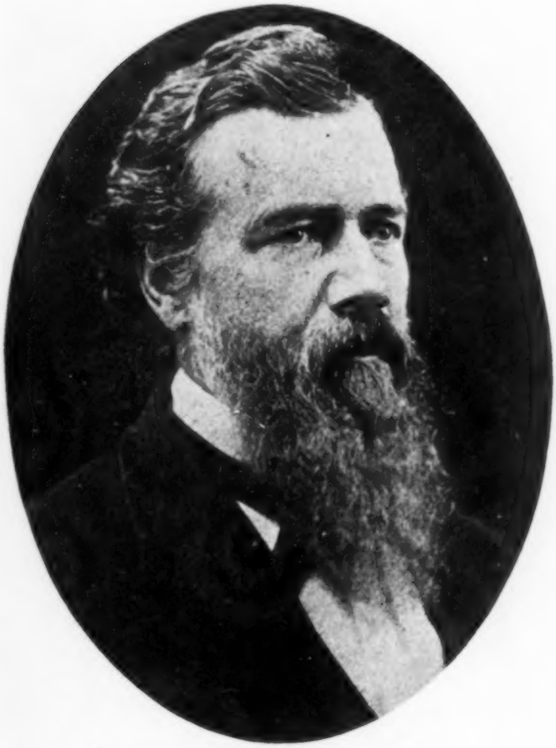
Henceforth Fitch devoted himself to this study. In 1848, he was engaged by the New York State Agricultural Society to make a survey of Washington County, the results being incorporated in the *Transactions* of 1848–49. Previous to this time, however, he had contributed numerous articles to the *American Quarterly Journal of Agriculture and Science*, which had been projected by Emmons. Among the subjects which he treated were the wheat midge, the Hessian fly and the currant worm. At last, in 1851, after he had collected and classified a large number of specimens for the State Museum, he prepared a catalogue of homoptera which is still valued by specialists. In view of his reputation, it was natural that when the legislature in 1854 appropriated funds for the employment of an official entomologist—the first in America—he should have been selected for the position. During the next thirteen years, a period in which he issued a series of annual reports, he made secure his



ASA FITCH, JR., '27
Asa Fitch, Jr. (1809–1878). State Entomologist of New York.

place as the "father of economic entomology." Although Van Rensselaer's aspirations regarding agriculture were soon obscured by the claims of industry, they have thus been realized in the activities of the national bureaus which are the legitimate descendants of the small organizations established by Emmons and Fitch.

The part played by the graduates of the institute in the first colleges of agriculture was no less important. West of the Alleghany Mountains, they found people peculiarly responsive to the theories of education which they had brought from Troy. The Morrill Act of 1852, foreshadowing the type of institution which Eaton had envisaged, offered them an opportunity of which they took full advantage. When the University of California was opened in 1869, Ezra Slocum Carr ('38), who had held the chair of chemistry and natural history and of chemistry as applied to agriculture in the University of Wisconsin, was called upon to become first professor of chemistry as applied to agriculture, or, as



EZRA SLOCUM CARR, '38
Ezra Slocum Carr (1819–1894). Professor of Natural Science in Middlebury College. Professor of Chemistry and of Natural History in the University of Wisconsin. State Superintendent of Education in California.

he was more often called, merely "professor of agriculture." The career of Hall, however, offers an even better illustration of the ideas which Rensselaer men carried beyond the Mississippi. In connection with the Iowa State Geological Survey, he became first professor and head of the department of natural history in the university, which he helped to establish. Though he apparently never delivered any lectures, he insisted not only on the importance of botany, zoology, geology and mineralogy from an academic point of view but also upon the necessity of considering their applications to agriculture. According to President MacBride, he anticipated the progress of the commonwealth in rural education. In similar paths the alumni were also trail-breakers; for George Hamill Cook ('39)—like Hall, an adventurer in many fields and professor of geology and agriculture in Rutgers College—became director of the first experiment station in New Jersey, one of the earliest on the continent. In the bureaus, colleges and laboratories devoted to

GEORGE HAMILL COOK, '39

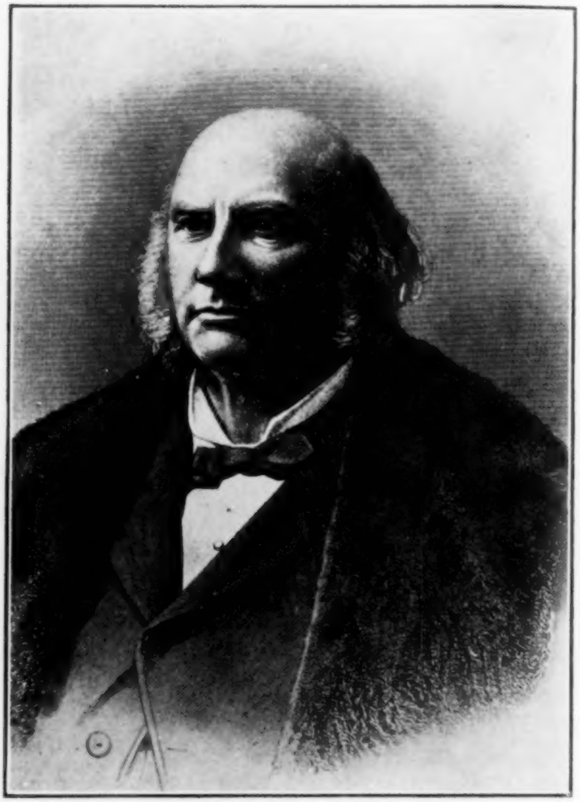
George Hamill Cook (1818–1889). Senior Professor and Professor of Chemistry, Mineralogy and Zoology in Rensselaer Polytechnic Institute. Professor of Chemistry and Natural History in Rutgers College. State Geologist of New Jersey. Director of the New Jersey Agricultural Experiment Station.

agriculture the ideals of 1824 still linger, although the students of the institute no longer "amuse" themselves on pleasant afternoons by studying vegetables or pruning trees on "well-cultivated farms" in the neighborhood.

The interrelation of the natural sciences before 1875 is especially noticeable in the case of those which belong to the second group. In the early part of the nineteenth century, "natural science" and "experimental philosophy" went hand in hand. It is difficult to divorce them. In fact, three graduates of the institute, the most distinguished of whom was John Pemberton, Jr. ('60), held professorial posts under this double-headed title at the United States Naval Academy. By 1850, however, physics was able to stand alone. Since most of the alumni, however, were teachers and not investigators, they have left little trace of their labors, except in the institutions which they served, although George Washington

HENRY AUGUSTUS ROWLAND, '70
Henry Augustus Rowland (1848–1901). Head of the Department of Physics in Rensselaer Polytechnic Institute. Professor of Physics in Johns Hopkins University.

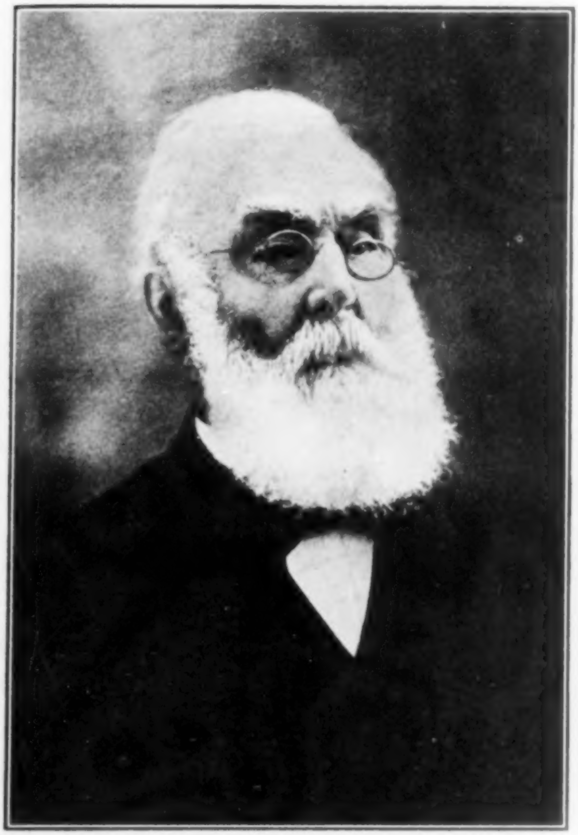
Plympton ('47) must be credited with many advances at both the Brooklyn Polytechnic Institute and the Cooper Institute. In Michigan, also, De Volson Wood ('57), who, with President Tappan, had been requested by the Board of Regents to formulate a policy to govern the teaching of the sciences, inaugurated the system of independent colleges for the pure and applied sciences which has been adopted by most, or all, of the state universities. The one alumnus, however, who left a permanent impress upon his generation was Henry Augustus Rowland ('70). Since his father, grandfather and great-grandfather had been clergymen, graduates of Yale, he was naturally sent to Newark and Andover to prepare for college. So great was his dislike of Latin and Greek, however, and so absolute was his devotion to mathematics and mechanics, that he was eventually allowed to enter Rensselaer, where, in spite of the meagerness of its equipment, he immediately felt at home. Except for a couple of terms at Yale, he spent the next five



EBEN NORTON HORSFORD, '38

Eben Norton Horsford (1818–1893). Rumford Professor of Chemistry in Harvard University. President of the Rumford Chemical Works.

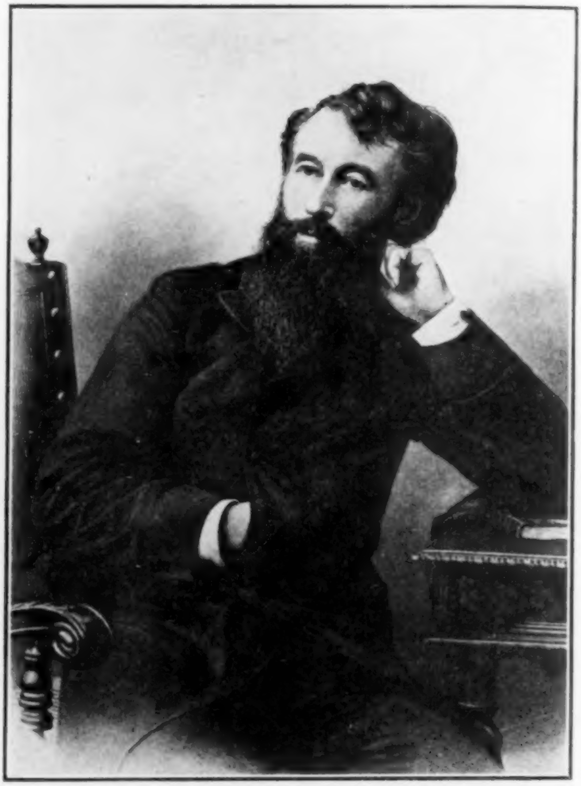
years in Troy. Graduated as a civil engineer, he passed a year in the field and another as instructor at Wooster, Ohio. In 1872 he returned to the institute. During the next three years, in which his salary as assistant professor of physics was decreased—for such was the agreement—as the appropriations for apparatus were increased—he began the investigation of magnetic permeability which established his reputation in Europe. As a result, he was appointed first professor of physics in Johns Hopkins University; and, in 1876, after a trip across the Atlantic to purchase supplies, he set up his "shop" in the two houses which he was to make famous. Born at a fortunate moment and called to a chair carrying with it opportunities for research unrivalled in America, he influenced the study and teaching of physics in a manner which is not likely to be paralleled in the future.



JAMES HALL, '32

James Hall (1811–1898). Professor of Chemistry and Physiology in Rensselaer Polytechnic Institute. State Geologist of New York for the Fourth District. State Geologist and Paleontologist of New York. State Geologist of Iowa. Professor of Natural History in the University of Iowa. State Geologist of Wisconsin. Professor of Theoretical, Practical and Mining Geology in Rensselaer Polytechnic Institute. Director of the New York State Museum of Natural History.

Because of the far-reaching results of his experiments, some comment on them is imperative. As I suggested in the last paragraph, he began in Troy those dealing with the maximum magnetization of iron, nickel and steel which led to new and revolutionary conceptions of magnetic phenomena. As a result, the laboratories of the institute are associated with the discovery and announcement of the principle of the magnetic circuit. In addition to the studies leading to the establishment of this analogue of Ohm's law, Rowland laid at Rensselaer the foundations for his classic re-



JAMES HENRY SALISBURY, '46

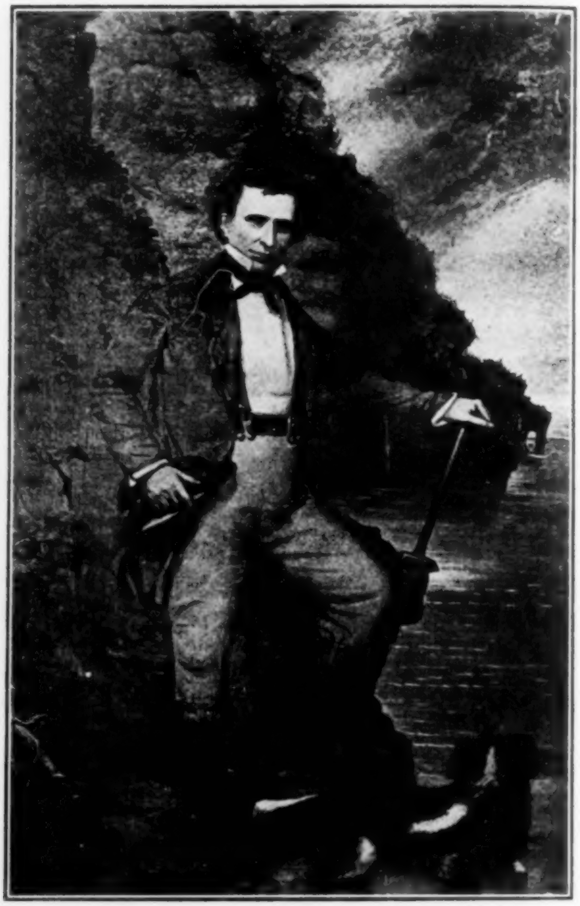
James Henry Salisbury (1822–1905). Chief of the Chemical Department of the New York State Geological Survey. President of the American Institute of Micrology.

searches on the magnetic effect of electrostatic charges in motion. At any rate, it is evident that he proposed to von Helmholtz certain procedures which he had not been able to employ because of lack of apparatus. Of his work at Johns Hopkins little need be said. While there he completed his investigations relating to the mechanical equivalent of heat. Though less original and less daring than those which marked his first professorship, they have been no less useful. At Johns Hopkins, also, he conducted his experiments on magnetic convection. His most epoch-making contributions, however, were those connected with the development of spectroscopy, a field in which he made himself supreme. In addition, however, he devoted his energies to the determination of electrical units of measurement, a subject to which he had been attracted while at the institute. As president of the Congress at Philadelphia, in 1884,

MICHAEL TUOMEY, '35

Michael Tuomey (1835–1857). State Geologist of South Carolina. State Geologist of Alabama. Professor of Geology, Mineralogy and Agricultural Chemistry in the University of Alabama.

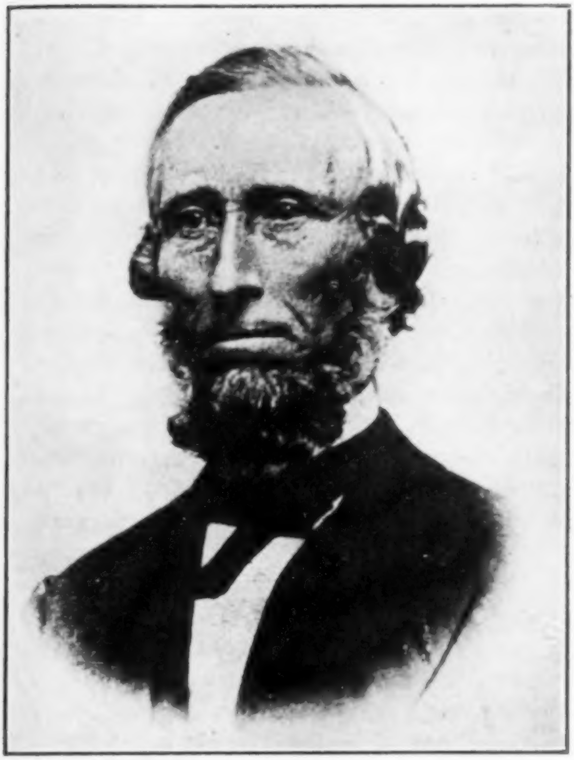
and the International Chamber at Chicago, in 1893, he aided materially in the evaluation of the ohm, the volt and the ampere. Though many of his labors were reflected in the advancement of electrical engineering, Rowland seemed, to the unthinking, remote from practical affairs. Tall and ascetic in appearance, the founder and first president of the American Physical Society, with an intense interest in literature and a passionate devotion to music, he is still regarded primarily as an academician. Nevertheless, though he was a scholar, he was also a mechanician. His accuracy in observation and precision in thought were matched by his inventiveness and mechanical skill, without which his gratings could not have been manufactured. There can be little doubt that, if he had desired, he could have been a great engineer. As it was, he was often consulted on matters of importance. Moreover, during the latter part of his career, he showed by his studies of alternating currents and telegraphic systems that he had never lost his early interest in



DOUGLAS HOUGHTON, '29
Douglas Houghton (1809–1845). State Geologist of Michigan. Professor of Geology, Mineralogy and Chemistry in the University of Michigan.

the applications of science. In all, there is no more significant figure in the history of physics in the United States.

Though there is no such outstanding name as Rowland's among the graduates of the institute who devoted themselves to chemistry before 1875, their contributions to the new learning were highly significant. During the second and third quarters of the nineteenth century, the subject was generally associated with geology and mineralogy; and for that reason it might well be considered with them. By the end of this period, however, it had established its claim to independence. The story of its evolution, as it can be traced in the careers of the alumni who aided in its advancement, is full of in-



ABRAM SAGER, '31

Abram Sager (1810–1877). Chief of the Botanical and Zoological Departments of the Michigan State Geological Survey. Professor of Botany and Zoology in the University of Michigan. Professor of the Theory and Practice of Medicine. Dean of the Faculty.

terest. As with botany and zoology, Eaton's name again emerges. In 1821 he had published his "Chemical Note Book," and in 1822 his "Chemical Instructor." In the list of subjects which he professed in 1824, chemistry stands first. Moreover, in the early bulletins, attention is continually directed to its importance in the world of affairs. In one of these pamphlets, published before either the Lawrence Scientific School or the Sheffield Scientific School had been organized, the preface consists of little more than an extended quotation from one of Liebig's essays. Under these circumstances —especially as Eaton had given, before 1828, thirty courses, each containing at least six hundred experiments—it is not surprising that the foundations of the departments of chemistry in about twenty institutions of high rank were laid by graduates of the institute.

In keeping with its traditions, most of them were attracted by its applications to agriculture or industry, although, in some instances, their professorships did not relate to either. Houghton, for example, was the first professor of the old triumvirate—geology, mineralogy and chemistry—in the University of Michigan. Carr, as I have indicated, introduced the subject in the University of Wisconsin. After eleven years at Madison, where he had also been professor of chemistry as applied to agriculture, he accepted a similar position in the University of California. In the application of chemistry to industry the contributions of the alumni have naturally been even greater. In the early days of the nineteenth century, two of them stand out with considerable distinctness—James Curtis Booth ('31) and Eben Norton Horsford ('38), whose careers were similar in many respects.

After receiving his bachelor's degree from Pennsylvania, Booth, who had little patience with the theoretical demonstrations of *alma mater*, entered Rensselaer. More determined than ever to carry out his plan of making the laboratory "a miniature factory" and the factory "a mammoth laboratory" he spent nine months in Hesse-Cassel and as many more in Berlin and Vienna. Returning to America as the first student who had sat under the masters of Germany, he organized in Philadelphia a laboratory for analysis, research and instruction. Moreover, in addition to his duties as head of this famous institution, the first of its kind, which is perpetuated by the firm of Booth, Garrett and Blair, he served as professor of chemistry applied to the arts in the Franklin Institute and later in the University of Pennsylvania. In the meantime, however, he had turned aside to geology and mineralogy. As a result of his studies of nickel, which he introduced into the coinage of the United States, of cobalt, of gold and of silver, he was appointed melter and refiner of the mint at Philadelphia. As director, he designed its furnaces, which he improved from decade to decade, and developed many original procedures. All his work, however, was not so directly utilitarian; for in both organic and inorganic chemistry he undertook many researches that were distinctly academic. One of the first presidents of the American Chemical Society, he wrote numerous monographs as well as most of the chapters in his epoch-making "Encyclopaedia of Chemistry, Practical and Theoretical" (1845–50). It is no exaggeration to refer to him as the most distinguished chemist of his day.[1]

[1] For an interesting and valuable sketch of Booth, see Provost Edgar F. Smith's monograph, "James Curtis Booth, Chemist, 1810–1888," n. p., n. d. (Read on September 9, 1922, before the Historical Section of the American Chemical Society.)

Almost parallel with his career was that of Horsford. Interested likewise in geology, the latter served under Hall and Emmons. Finally, after a couple of years under Liebig, he was invited to Harvard, where, as Rumford Professor of the Application of Science to the Useful Arts, he induced Abbott Lawrence to establish a school devoted to analytical and practical chemistry. In this, the Lawrence Scientific School, he conducted the first laboratory courses of any importance given in the university. During most of his tenure, it is interesting to note, President Eliot was assistant professor, resigning, when Horsford became head of the Rumford Chemical Works, to establish the department of chemistry in the Massachusetts Institute of Technology. Even after his acceptance of this position, however, Horsford maintained his interest in education, assisting materially in the development of Wellesley College. Not only did he endow its libraries and laboratories and provide the material and apparatus necessary for instruction in the physical and biological sciences, but he also introduced a system of pensions for the president and heads of departments as well as an arrangement for sabbatical years in Europe. Nevertheless, his chief contributions were made through his patents, which led to the establishment of many successful enterprises; and it is as an industrial chemist that he deserves to be remembered.

Great as have been the services of the graduates in botany, zoology, physics and chemistry, it is doubtful whether they have equalled those in geology and mineralogy. As in the other sciences, the original stimulus came from Eaton. Of his surveys in New York, I have already spoken. In addition to his reports upon these surveys, he was the author of four treatises upon geology. These monographs, one of which contains the first illustrations of organic remains, are the prototypes of nearly five hundred studies written by graduates who have followed in his wake. Through their contributions it is possible to trace the progress of geology and mineralogy in the United States during the nineteenth century. Indeed, of eleven "events and forces" which, according to Professor H. L. Fairchild,[2] influenced development before 1848, five were connected with the institute. In the east, the south and the west, its influence was a compelling force in the local bureaus and universities.

During the first part of the period, the New York State Geological Survey occupied a dominant position. At first, in 1836, it was divided into four sections, one of which was entrusted to Emmons, who discovered the Taconic (Cambrian) system, and who, in Troy, Williamstown and Albany, labored zealously in school and college

[2] "The development of geologic science." In SCIENTIFIC MONTHLY, July 1924, xix, 77–101.

for the advancement of his favorite study. The importance of these labors is emphasized by the fact that his old home in the Capitol City—the house in which the Association of American Geologists was projected—now bears a tablet erected by the authority of its lineal descendant—the American Association for the Advancement of Science. A year after Emmons began his work, Booth, in Pennsylvania, became assistant to Professor Rogers. In 1837, also, he was appointed chief of the newly organized Delaware State Geological Survey. After the failure of the New Jersey Geological Survey, Cook, who had been assistant and who later accepted the responsibility of administration, made many notable advances in methods of mapping. Though it would be pleasant to follow the alumni elsewhere in the east, their services in New York demand special attention. Of the graduates associated with the State Survey, Hall was undoubtedly the most eminent. Under Emmons, he was assistant in the Second Division. In 1836, he was appointed geologist for the Fourth District; in 1843, paleontologist of New York; and, in 1866, director of the State Museum. For nearly sixty-five years—during which time he served as first president of the American Geological Society and as one of the first presidents of the American Association for the Advancement of Science—he was immersed in public affairs. For many years, also, he was professor of geology and mineralogy in the institute. With him, or under him, served many graduates, such as Horsford, whom he induced to enter Rensselaer; Carr, with whom he was afterwards associated in Wisconsin, and James Henry Salisbury ('46), principal of the chemical department at Albany and, later, president of the American Institute of Micrology. His reports—filled with echoes of old controversies long since forgotten except by specialists—illuminate every phase in the development of his chosen field in the Eastern States. He has been called the "founder of American stratigraphy," the "father of invertebrate paleontology," the "master" without whose discoveries, in the words of James Dwight Dana, "the geological history of the North American Continent could not have been written." In recognition of his unique place in the development of science, the Association of American State Geologists in 1916 placed a tablet on the building which, for nearly fifty years, he used as his office and laboratory.

During this period, the graduates of the institute were not idle in the south. Though Hall refused an offer of the professorship of geology and agricultural chemistry in the University of Alabama, with the promise of a survey if interest could be aroused, and also a position in the Missouri State Geological Survey, he lent material aid, through recommendation or advice, in both Mississippi and

Texas. Other Rensselaer men, however, were personally active. Emmons, in North Carolina, who was engulfed in the maelstrom of the war, was one of the most distinguished. Michael Caleb Briggs, ('35), who had been associated with the Ohio State Geological Survey, joined Rogers in Virginia. In 1847, his classmate, Michael Tuomey ('35) became state geologist of South Carolina; in 1847, professor of geology, mineralogy and agricultural chemistry in the University of Alabama; and, in the following year, state geologist. His reports are among the earliest and the most comprehensive published in the south.

In the west, the story is much the same. In 1837, Houghton, aided by Sager, had undertaken the Michigan State Geological Survey. Next year he was appointed professor of geology, mineralogy and chemistry at Ann Arbor. Like Houghton, Hall, who was summoned to organize the Iowa State Geological Survey in 1855, also ranked as first professor of geology in the university. As early as 1841, he had led an expedition into the Middle West to extend the geological boundaries of New York. On this trip he had explored not only Michigan but also Illinois, Indiana, Iowa, Missouri, Ohio and Wisconsin. His thoughts were thus turned westward at an early date. Meanwhile Carr, who had been one of his assistants in New York, and who, as I have intimated, had been called to a professorship in the University of Wisconsin, had become one of the commissioners of the Geological Survey. Through him, probably, Hall became commissioner and, later, superintendent. Of Hall's influence in other states and provinces—for his services were international—Dr. John M. Clarke—like Hall, director of the New York State Museum and long professor of geology at the institute—has touched in his admirable biography,[3] through whose pages move the alumni who made the valley of the Hudson, for no inconsiderable period, a rallying point for the scholars of America.

Any summary of their achievements in the natural sciences ought, however, to include an account of their contributions in fields besides botany, zoology, physics, chemistry, geology and mineralogy; for in some instances they were able to assist materially the younger universities, like Cornell, where Estévan Antonio Fuertes ('61), director of the college of civil engineering and professor of astronomy, erected the Barnes Observatory. Especially should any summary include some reference to those who became teachers in the secondary schools in the towns and cities of the east. Far in advance of their colleagues, some of them, like Fay

[3] "James Hall of Albany, Geologist and Paleontologist, 1811–1898." Albany, 1921.

Edgerton ('26), under whom James Dwight Dana studied in the Utica Museum, realized in their lives the ideals of Amos Eaton. If the accomplishments of these two groups are linked with those of their fellow graduates, the high phrases of the frayed and yellowed catalogues that appear quixotic at times in view of the poverty of the institute and the slightness of its equipment assume a new dignity and a new significance—the dignity and significance of a great tradition informing to-day in every state the spirit of those who have risen to be its heirs.

THE ORIGIN OF LIFE

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At the remotest frontiers of man's most penetrating and imaginative thought there has always lingered the dream—perhaps the hope—that the age-old mystery of the origin of life would some day be solved. The remarkable forward strides that have been taken in the physical sciences in the last two decades, replete with significance for the progress of biological thought and study, have strengthened rather than weakened that hope. It is my purpose in this brief paper to recall to your minds, among other things, some of the theories, or at least speculative hypotheses, which have been put forward in the past to account for the origin of life on our planet, but chiefly to review critically some of the consequences of these hypotheses in order to test the soundness of the latter and to propose a view of my own relative to the problem in hand. To the interested reader, it is probably superfluous to enter into a disquisition on the difficulties of the task in question. Needless to say, finality of judgment in the premises is proscribed and I do not seek to be dogmatic in any part of my discussion. Inconclusive indeed I must be, but I venture to hope that my analysis of the problem may contribute to progress, or at least to clarification of our thought.

The Aristotelian conception of the origin of many forms of animal life from decaying or dying pre-existing forms held sway during the greater part of the period of the recorded history of man. In fact, the theory of spontaneous generation did not receive its death-blow until our own period in man's history had almost arrived. But before the simple and convincing experiments of Pasteur had put the final quietus on the theory of spontaneous generation, many investigators had clearly shown the fallacy thereof. Before the last third of the seventeenth century, Redi had demonstrated that maggots never appeared in meat which was protected from flies, and that only when flies were permitted to lay their eggs in the meat were maggots ever developed there. Redi's findings were challenged by Needham, whose contentions were supported by the high authority of Buffon, but all these objections were shown to be specious by the experiments of Spallanzani, of Schwann, and of Cagniard de la Tour. The investigations just mentioned formed the solid foundation upon which Pasteur built his celebrated struc-

ture of logic and experiment, whose successful establishment led to the death of the theory of spontaneous generation. But has that theory really been annihilated? Are we ready to subscribe to all the implications of such alleged annihilation as well as to the apparent soundness of the arguments against the theory? These questions deserve close investigation and study. It is not obvious to many students of biology that the establishment of the proof that the forms of life of which we have knowledge are produced only through the normal reproductive processes of the same or closely similar forms constitutes no denial that other possible forms whose nature lies beyond our ken may not be produced from non-living matter. In other words, it is realized by relatively few people that the theory of spontaneous generation which died so hard might not have been wholly wrong. Its obvious claims and implications were, of course, fallacious, but its more recondite and abstruse inferences, whether fully appreciated by its proponents or not, are not susceptible of banishment without violence to the principles of clear thinking and unprejudiced, critical judgments. One question at least has always remained to confuse and baffle the opponents of the theory of spontaneous generation and that is the following. If Harvey's celebrated dictum—*omne vivum e vivo*—is unqualifiedly correct, how can we explain the beginnings of life forms? That question is not regarded seriously by many biologists, because they do not admit that there was any more need for a beginning of living than for a beginning of non-living matter. Many biologists of that school assert that life had no beginning, but has always existed like the inorganic matter in sidereal space. Making such an assertion is, of course, begging the question. It is unsatisfying intellectually to be confronted by a hypothesis of that sort. Besides, such evidence as may be at hand and the logic concerned therewith are subversive of the view in question. While the establishment of the validity of the theory of evolution does not constitute a decisive denial of the view that living matter had no beginning, it does, at least, supply strong presumptive evidence against such a hypothesis. It would not seem reasonable, in the face of the splendid paleontological evidence which we have of the evolution of some animal forms, to contend against the likelihood that life in the universe did have a beginning and did pass through an orderly development from more simple to more complex forms. But if that is true, does it not seem irresistible to conclude that there must have been very simple forms at the bottom of the evolutionary ladder? If so, how could such simple forms have come to be except by synthesis from the chemical elements or compounds?

With this brief introduction, let us consider the theories which have been advanced to account for the establishment of life on our

planet. The first of these deserving of notice is one known as the Cosmozoa theory, which is built on the assumption that life first came to our planet from other planets. This type of theory in the field in question, first suggested independently by Richter, Helmholtz and Kelvin, is, perhaps, best known through the discussions of Arrhenius in "Das Werden der Welten." As all of you are doubtless aware, Arrhenius assumes that the pressure of light radiation might be considered of sufficient magnitude to overcome gravitational forces in so far as microscopic spores and similar living units are concerned and that such bodies might be conceived in time as drifting from other planets to our own. This would result in the establishment of life forms on our earth with relatively simple beginnings. Like the general view to which I have made reference as opposed to the idea that life ever had any beginning, the Cosmozoa theory begs the question and is unsatisfying to the critical and imaginative mind. It explains nothing as regards the origin of life. Moreover, it is open to other serious objections. The enormous distances in space which must be traversed by these hypothetical "seeds" of this world's life, as we may call them, would require such long periods to cover that it is questionable if the resistance of microscopic spores or other organisms to conditions unfavorable to life for such long periods is great enough to be equal to the ordeal. This argument against the Cosmozoa theory, however, is not as cogent as the one that the low temperatures in interplanetary space would destroy any form of life passing through such space. To offset this criticism, it has been argued that the experiments of Dyer and others have shown that even seeds of the higher plants may withstand the temperatures of liquid air and liquid hydrogen for many hours and still remain viable. But the difference between many hours and many years or centuries is obviously great and the reply to the criticism is, therefore, not satisfying. To be sure, dormant forms of life, as Arrhenius points out, should show prolonged resistance to the conditions obtaining in cosmic space, because of the absence of water vapor and the exceedingly low temperature there, which permit of very slow respiration. But even dormant forms of life must respire and it seems reasonable to conclude that even very slow respiration could not be continued almost interminably at such exceedingly low temperatures as those in question, notwithstanding Loeb's view on that point. In spite of many reports to the contrary, there is no authentic record of viable seeds older than 150 years and there is only one case on record for that length of time. Granted that the conditions in cosmic space would so far diminish the rate of respiration as to give greater longevity to the hypothetical spore, it is difficult to see

how life might be maintained for the long periods necessary to bring life from distant planets to the earth, especially when prolonged low temperatures are probably detrimental even to dormant life forms. More important still is the argument that no case is known in which living cells, dormant or otherwise, have been proved to exist without oxygen. How could we expect spores from other planets to exist in space for centuries without oxygen?

While, therefore, the Cosmozoa theory can not be definitely proved or disproved, I feel that the arguments which I have advanced against it constitute strong presumptive evidence that it is not valid.

The Cosmozoa theory constitutes an attempt to generalize human thought on a great problem. It leaves many loose ends and begs many questions. The more modern theories on the subject are more specific than the cosmic theories to which I have adverted. They assume that life had a beginning and with that assumption construct specific hypotheses to account for its probable origin. To a consideration of some of these theories we may now address ourselves. The presence of proteins is the distinctive feature of life. The remarkable progress made in organic chemistry in the last two or three decades has not, however, included the discovery of a method for synthesizing proteins. As a result, mystery still shrouds the future answer relative to the nature of proteins and hence that of the nature of protoplasm. Because of the fundamental importance and indispensable character of proteins to protoplasm, it becomes pertinent to inquire, if only speculatively, into the identity of organic groups, the radicals of the older organic chemists, which constitute the nuclei, so to speak, of protein compounds and which probably play a rôle in contributing to the amazingly labile nature of the proteins and of protoplasm. With this point of view in mind, Pflüger has pointed out the fundamental difference obtaining between the "dead" proteins, as he calls them, such as egg albumin, and the living proteins which play an active part in the chemical activity of protoplasm. This difference consists in the fact that only the "living" proteins either contain the cyanogen group or can be artificially produced from compounds of cyanogen by subtle changes in the molecular or atomic structural arrangement. Because of this Pflüger believes that the cyanogen group is an integral part of the molecular complex of the living proteins. Since it is possessed of enormous amounts of energy through the large absorption of heat involved in its formation, he argues that it induces energetic internal motion in the protoplasm. Further, on the fact that cyanogen and its compounds are produced only in an incandescent heat, he bases his belief that cyanogen

was the first organic compound characteristic of life which was produced when the earth was still in the incandescent stage of its history. Pflüger then points out there are so many analogies in the chemical behavior of living proteins and cyanogen that cyanic acid may be, itself, regarded as a half-living molecule. The tendency of cyanogen compounds to decompose and react again with other carbon compounds at similar temperatures would result in new substances, which, in turn, react with water and salts to form the highly labile proteins of living matter. These were the foundation stones for the construction of highly specialized protoplasmic bodies of living cells, as we know them. In Pflüger's theory, therefore, we see an attempt based on more definite scientific conceptions than those we have previously considered, to visualize a series of reactions by which living matter might be constructed from inorganic matter, with the central and pivotal postulate relative to the behavior of cyanogen and its compounds. It is to be noted particularly, however, that in this theory the beginning of life is still assumed to be in substances of the high complexity of protoplasm, or of the living proteins. The theory is one, then, which proposed to account for the mode of construction of protoplasm, but it does not envisage the problem of the origin of primitive life forms, from the point of view of their antedating the existence of proteins.

Like Pflüger, Benjamin Moore has attempted the formulation of a theory to which the concept of the origin of life from simple inorganic substances is basic. Moore proposes a law of complexity, whose essential feature consists in the assumption that matter tends to assume more and more complex forms in labile equilibrium, so far as its energy environment will permit. Thus oxides, carbonates and similar substances will be produced when conditions are propitious for their formation in accordance with the idea that increasing complexity in the composition and structure of matter is its inevitable destiny. Moore believes that at a proper stage in the earth's development, the temperature conditions were just appropriate in the waters of this terraqueous globe for the formation of colloidal iron and silica. The colloidal iron, as is well known from certain experimental evidence, obtained by Moore and by others, is exceedingly active in catalyzing certain reactions between CO_2 and H_2O in the presence of light, which result in the formation of simple organic compounds. These compounds condense as postulated by Baeyer in 1877, to form the more complex sugars. It may be said to the credit of Moore's view that recent experimental evidence adduced by Baly and Heilbron at Liverpool not only confirms Moore's simple experiments, but amplifies and adds to a marked

degree fundamental information on the experimental production *in vitro* of complex organic nitrogenous compounds, among which was an alkaloid known as coniin. It would take us too far afield to consider adequately the Baly and Heilbron experiments and the equally important work of Oskar Baudisch, but I can not leave them without stating my opinion that those contributions are among the most important in the biochemistry of to-day. I believe, moreover, that they will be found to be possessed of a profundity of significance which few scientists realize, or are willing to admit to-day for the solution of the riddle of life's origin. Returning, however, to Moore's law of complexity, we discern in it and its outgrowths the explanation for the formation of atoms, molecules, colloids and finally living organisms, and the heights of organic evolution itself, when a sufficient degree of complexity and a proper orientation of the atoms and molecules has been attained. Let me point out here again, as in the case of Pflüger's theory, that the conception that proteins and protoplasm are essential to life is, in Moore's view, an ineluctable postulate.

The other theories which have been proposed on the origin of life are not sufficiently different in essentials from those I have discussed to deserve more than passing mention. F. J. Allen argues that the conditions which are propitious for the maintenance of life must also be the conditions for its origin. On the assumption of the planetesimal theory of the origin of the earth, therefore, Allen believes that life could not have been produced outside the range of the freezing and boiling points of water. At any rate, he believes if life could be produced outside of that range of temperature, it must be very different from the life which we know. Obviously, this must be so, but it is a confession of weakness in the theory. There is no reason, so far as I can see, why a given form of life should be assumed to be the only one deserving of consideration just because our imaginations are not equal to the task of conjuring up some other form of living substance.

Troland's enzyme theory assumes that enzymes produced in some fortuitous fashion became the centers of subtle changes which resulted in the formation of accelerated reactions between the substances soluble in the warm waters of the earth's surface. These would cause the formation of immiscible substances in which the enzyme continued to play the rôle of accelerator until some primitive jelly-like mass with living characteristics would be produced. It is obvious that the Troland theory is vulnerable because it assumes the beginning of life to be contingent upon the existence of an autocatalytic enzyme which is, itself, so complex a substance that chemists have not succeeded in discovering its nature. In other

words, it seems to me that if we are to begin our theory of the origin of life by postulating the sudden appearance of an autocatalytic enzyme under primal earth conditions, we might well postulate the sudden appearance of a living amoeba or even something much more complex.

H. F. Osborn's theories are of far less importance, in my judgment, than those of Allen and Troland, because they add nothing new to the earlier theories. They consist in rephrasing of the older theories and a refurbishing of them with certain observations and experimental data which throw no light on the real problem in hand.

The foregoing discussion has dealt in the main with two points of view in reference to the origin of life on our planet. One is concerned with explaining the beginnings of life on the earth with simple forms, but which, none the less, were composed of highly organized material transported hither from other spheres in the universe. The other conception is that the first living unit originated on our planet through interaction under appropriate conditions of various chemical substances, first simple, then more complex, until a protoplasmic substance with the attributes of life came into being. I desire now to direct your attention to a theory of my own which seems to me to be in greater consonance with facts and with clear reasoning than those to which we have thus far given consideration. It seems to me illogical to assume that such a large gap exists between living and non-living matter at the point of genesis of the latter, as the foregoing theories have postulated. The beautiful symmetry of the series of organic substances known to the chemist would seem to me to argue for a gradual transition rather than an abrupt break between non-living and living matter. In order that this may be true, however, it is necessary that simpler substances than protoplasm, or even than proteins, should have become possessors of the attributes of life. I have, therefore imagined that instead of a very complicated bit of protoplasm, no matter how small in size, composed of many, or at least of several molecules, including protein molecules whose structure we do not yet understand, the beginning of life forms was in a living, single molecule, much simpler than the protein molecule. Thus there is no reason, it seems to me, why a single molecule of a substance similar in composition, but different in structure from a molecule of an amino-acid or of a polypeptid, should not have become possessed of the attributes of life long before protein molecules or protoplasm could have been formed. It is well known to those who possess even an elementary knowledge of chemistry and particularly organic chemistry that it is not so much the composition as

the structure of a substance which determines its properties. Thousands of substances are known whose composition in respect to the kinds of elements entering therein is the same, and, in many cases, the elements occur in them in the same proportions and yet the properties of those substances are markedly different from one another. We know that this is because of a different arrangement of the same atoms in the molecule, just as we can make many designs or patterns with one kind of block or brick. But if it is possible to change the physical and chemical properties of substances so markedly by changing the arrangement of the same atoms in the molecule, why isn't it entirely reasonable to suppose that such marked change may go so far as to invest certain molecules with the powers or characteristics which we deem distinctively diagnostic of life? Thus, we can imagine that in the early history of the terraqueous mass which was then the earth, with high temperatures and great chemical and electrical activity existent, such substances as carbon dioxide, water and nitrates may have been caused to combine in such fashion as to produce a pattern of molecule in which the behavior of the substance in regard to motion, growth and reaction with its environment was not, perhaps, the same but, in a primitive way, similar to that of an amoeba, and we would have our first living molecule. This molecule would then, under certain conditions, react with other molecules and gradually build up more and more complex chemical aggregates until perhaps after geologic ages, the proteins and protoplasm itself would be evolved.

This view of the problem is, perhaps, rendered more readily comprehensible by a consideration of some facts in the region of life forms. The smallest known units of living matter are single protoplasmic cells known as bacteria. But for several years past, we have known that certain bacterial forms must exist which we can not see, because we have apparently reached the limit in the grinding of lenses for magnification with effectiveness. Other tests which are available to us, however, leave little room for doubt relative to the existence of these so-called filterable viruses. For example, by a highly developed technique, bacteriologists have recently succeeded in growing some of these filterable viruses (which are so small as to pass through the pores of some clay filters) on special media in which the colonies of the organisms appear as very tiny dots on the plates. Each colony represents the multitudinous progeny of one original cell which is too small to be visible even under the most powerful microscope. It is noteworthy, further, that this type of investigation has reached its most perfect form to date in the remarkable work of Olitsky and Gates at the Rockefeller Institute for Medical Research in New York, and published recently,

on the filterable virus which is the probable cause of influenza. Other filterable viruses are known whose cells are so small that even their colonies consisting of millions or billions are not visible under magnification. We do not even know that some of these infinitesimally small organisms possess protoplasm as do the bacteria and the higher forms. But whether they do or not, they are far removed, as one can readily imagine, from that simple form of matter which we must assume as the primordial form of life if we give heed to a few of the considerations involved in the question to which I have drawn your attention; and particularly to the unlikelihood of any sudden jumps in the evolution of matter which are of such magnitude as those which I have been discussing.

There are one or two further points connected with the subject of this paper which I should like to present. Investigators like Macfarlane at Pennsylvania and others have assumed that plant life must have preceded animal life in point of origin. This assumption is based on another assumption that there could have been no organic substances in the commonly accepted sense of the term without autotrophic organisms to build them. This appears to me to be a gratuitous assumption, since it would seem reasonable to suppose that in a certain part of the earlier history of this earth, temperature and other conditions must have been entirely equal to the production of many series of reactions resulting in the synthesis of a variety of organic substances. From that point of view, therefore, it is entirely conceivable that animals may have originated independently of plants and for all we know, earlier, rather than later, in the earth's history. Another assumption which is frequently made in scientific circles is that nitrogen-fixing bacteria must represent a very primitive form of protistic, if not of plant life. This conception is based obviously on the idea that any organism which possessed the power to synthesize its own nitrogenous foods from elementary nitrogen and other elements must have been the only one capable of existing in a world devoid of fixed nitrogen. But this, it appears to me, is the fallacy of the argument, *viz.*, to assume that there was little or no fixed nitrogen on the earth's surface at a period preceding the "dawn of life." It seems to me that if conditions were ever appropriate for the chemical and electro-chemical reactions by which nitrogen is made to combine with other elements, they were so at that stage in the history of the earth preceding the synthesis of living entities or contemporaneously therewith. Moreover, there is another reason for rejecting the view that nitrogen-fixing organisms were among the earliest of life forms on the earth. If conditions were not appropriate for chemical fixation of nitrogen in the periods in question, then, too, they must have been so for

carbon fixation, and no nitrogen fixation could occur through nitrogen-fixing bacteria without fixed carbon compounds of certain kinds as a source of energy. All claims for the primitive nature of Azotobacter and similar nitrogen-fixing bacteria, therefore, rest on an insecure, and, in my opinion, specious basis.

But if we return to a consideration of the autotrophic organisms, a little careful thought demonstrates the invalidity of regarding them as primitive organisms, even if they originated in the absence of organic compounds on the earth's surface. The green autotrophic plants possess chlorophyll, which seems to be indispensable to their ability to employ the energy of light in synthetic reactions. But chlorophyll is a substance of an extremely high degree of complexity in structure. It is fairly closely related in that and other respects to the haemoglobin of our blood. The high complexity of its structure, the specialized forms of it exemplified in chlorophyll (a) and chlorophyll (b) argue most emphatically and cogently against the probability that organisms possessing it are to be regarded as primitive. On the other hand, there exist a few groups of those wonderful, fascinating organisms known as the autotrophic bacteria which possess no chlorophyll, work in the dark, and yet, like the green plant, can synthesize their foods from simple inorganic compounds with energy furnished by certain chemical reactions which only those organisms, for example, the nitrifying bacteria, have the power of initiating, maintaining and accelerating. But while these organisms must be far more primitive than the green plant when studied from the present point of view, while they are very small and very simple as compared with other organisms of which we have knowledge, they are still extremely complex in that they are to be regarded as tiny, very tiny drops of protoplasm. In other words, even when we consider the simplest of known organisms, we are still very far from visualizing the really primitive forms of life, in my opinion.

Without indulging in the subtleties of philosophical method, I have endeavored to draw for you a picture of the workings of the human mind, on the oldest and perhaps most difficult—certainly the most fascinating—of human problems. This discussion is important not only because it aims at the clarification of our thought on the great riddle of the nature and origin of life, but because it contributes to a knowledge of the scientific methods and experiments which must form the groundwork of any rational view on the inceptions of those attributes which we associate with life. The amazing results obtained by physicists and chemists in recent months and years on the intimate structure of the atom and hence of matter itself exemplify strikingly the sublime heights to which

the human imagination and ingeniousness may attain. They indicate, moreover, that there is no limit, for all our human weaknesses and limitations, to which human thought may not aspire, in the solution of our most subtle and elusive mysteries.

And thus the world of science moves forward to its certain destinies. With the clear, open, eager and wholesomely curious eyes of youth, it scans avidly and hopefully the horizon which screens the unknown from view. It constitutes itself the rescuer and guardian of the vestiges of the inquiring spirit and exploratory temperament which, with our halting systems of education alone remain in the manhood and womanhood of to-day to remind us of the divine desire to know the causes of things and the truth about things, and is at once the inspiring and engaging, as well as most characteristic, attribute of youth and the freshness of childhood.

Nurtured thus in a spirit of hope and perpetual enthusiasm, the scientist must needs succeed in his age-old quest. Such success is bound no less to reward the labors of him who seeks to unlock the secret of life than it has already so bountifully repaid the discoverers of truths, less majestic and grand, less profound and impressive. With slow and measured step the scholar and investigator treads the narrow and difficult trail leading into the unknown. There is no dearth of new disciples to continue the search from the point at which the old explorers, fatigued but not daunted, have been obliged to give over their labors. It is with such a vision and in such a faith that we proceed to our appointed task of solving the riddle of life. Who can reflect with intellectual honesty upon the astounding discoveries of physics, chemistry and astronomy and deny that our reward at some point in the future awaits us? Who is so uncritical as to disparage the hope that the mind which can think about its own thinking and sit in judgment on its own judgments can also, somewhere, at some time, rise to the pinnacles of erudition, insight and ingenuity which will render clear its own origin?

I have attempted, I admit very sketchily and hastily, to describe a few of the important views which obtain in the world relative to the origin of life. I have also tried to appraise and criticize those views and introduce an additional view of my own. My purpose was not so much to present dissident views as to examine into the validity of any general view of this most important subject. I do not doubt that I have not made my meaning entirely clear, but if I have held up the mirror so that an occasional image has flashed on your vision in sharp relief, I am content.

DISEASES OF TONSILLAR ORIGIN

By Professor DAVID J. DAVIS

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In our laboratory we have been interested in tonsil diseases for several years. Since the watchword of the medicine of to-day is "prevention," I wish to point out, briefly, certain principles of preventive medicine and pathology as illustrated by our studies of this organ. Since many of my readers are not medically trained, I shall use as few technical expressions and terms as possible in presenting what I have to say.

My reasons for selecting this subject are, I feel, adequate. First, this organ from the standpoint of pathological and bacteriological processes is of peculiar interest and importance, because about it the etiology and transmission of many infectious diseases center. Second, it is of interest because of what already has been done, because of what has been done which should not have been done, and because of what still may be done to prevent and control disease. Again, many diseases of tonsillar origin are of such a character that they lend themselves readily to preventive measures. Nearly all operative procedures in this organ are for the purpose of prevention of disease, thus furnishing a striking illustration of the keynote of modern medicine, namely, prophylaxis.

Permit me just to recount some of the conditions in which this organ is either primarily or secondarily concerned. Acute follicular tonsillitis, commonly called sore throat, is one of the most common diseases. It is caused by a streptococcus. An especially severe variety of this condition is known as septic sore throat and occurs in epidemics, often spread through the milk supply. You are all, no doubt, familiar with the severer types of this disease under the term of quinsy. Many ordinary colds, including pharyngitis, laryngitis and often pneumonia involve more or less the tonsils. Diphtheria, measles, scarlet fever, Vincent's angina and several other diseases especially contagious in character may be mentioned here as primarily or secondarily involving the tonsils. General or systemic diseases of various kinds have now been traced to the tonsil as a primary focus from which point almost every tissue and organ of the body may be involved. In this connection, acute articular rheumatism and also chronic arthritis along with heart and other complications deserve especial mention.

for these cases when analyzed are usually dependent upon a primary tonsil infection. Two and a half million people in this country suffer from heart disease, and, as Sir Thomas Lewis says, when it is thoroughly grasped that infection has more to do with heart failure than strain or other mechanical defects at all stages of disease, then and only then is the natural history of heart disease understood. Now there are two chief infections which are responsible for heart lesions—syphilis and acute articular rheumatism, and the latter is primarily a tonsil disease. In the examination of the dead body with heart lesions, in tracing back the cause, there are two things we at once investigate, the syphilitic history and the tonsil and rheumatic history.

In the light of the above, therefore, it is clear how important it is to know thoroughly the pathology of this organ which, as it were, occupies the center of the stage in so many important diseases of both children and adults.

The tonsils are prominent accumulations of lymphoid tissue, located on either side of the throat, and covered by mucous membrane which at from eight to twelve points dips down into pockets or crypts to a depth of a centimeter or so. Considered by itself from the point of view of physiology, the tonsil is not an important organ, nor should we expect it to be. It is too superficial and too exposed, for Nature in the course of evolution has seen to it that the important vital organs are deep within the body where protection is greatest, leaving the less vitally important but protective mechanisms (skin, mucosa, adipose tissue, lymphatic nodes) more externally placed. We may look upon it as a part and a very small part of the extensive system of lymphatics of the pharyngo-intestinal system, all of which taken together may possess an important function, but a part and even a large part may be removed without serious disturbance so far as we now know.

Lymphatic nodes may be divided into two groups—first, the lymphatic nodes found along the respiratory and intestinal canal located under the mucosa and covered by a layer of loose, modified epithelium, apparently designed for absorption. Bacteria are always found normally in these nodes. They may be referred to as subepithelial lymphatic nodes. They have no afferent lymph vessels but an abundant supply of efferent vessels which invariably lead to a second deeper set of nodes which are called interstitial lymphatic nodes.

This subepithelial lymphatic tissue is frequently arranged in prominent projecting masses as in the human tonsil and in the Peyer's patches and often the surfaces are corrugated or grooved or pitted; the result being an increase of absorbing or secreting

surfaces. This, too, may be brought about at times by an evagination or tubular depression as occurs in the tonsil of certain animals like the cow and also in the appendix.

The location of the tonsils is strategic; they are prominent masses at the portal of two great systems, the respiratory and the gastrointestinal. We do not know to a certainty that there is any advantage to the body in this location, but we know that from the standpoint of disease transmission, viruses and bacteria of various kinds find it to their advantage to locate here; for as air, secretions, food, etc., pass back and forth over these structures, aided often by such processes as coughing, sneezing, talking and breathing, they are readily carried either to the outside of the body where they may be able to enter another body or deeper into the body, thereby extending their field of activities, all to the decided advantage of the micro-organisms in their struggle for existence.

I wish to call attention now to a point of interest in connection with the distribution of lymphoid tissue in the throat and gastro-intestinal canal in relation to the bacterial distribution in these localities. It is well known that lymphatic nodes are so distributed generally in the body as to protect it against the absorption of dangerous matter from various well-recognized sources. Indeed, lymphoid tissue occurs, generally speaking, only in those localities where absorption is occurring. So we have the clusters of lymphatic glands at the hilus of the lungs, of the liver, in the mesentery, in the axillary, inguinal and cervical regions, etc.

When one views the alimentary tract from the lips to the rectum, one observes two localities where striking accumulations of lymphoid tissue appear, namely, in the region of the throat, and in the lower small intestine, especially about the ileo-caecal valve and appendix. The intervening localities, like the stomach, duodenum, etc., have lymphoid tissue, but it is irregularly distributed and far less in quantity. *A priori,* this would indicate excessive absorption of dangerous matter in these localities and as a matter of fact this appears to be true. (Of course, I do not mean to imply that this is the only function of lymph glands.) For in these two localities, namely, the throat and the region above and below the ileo-caecal valve, we find normally the greatest number and variety of bacteria, as may readily be shown by making smear and culture preparations at intervals along the alimentary canal. If one would represent the amount of lymphoid tissue along the canal by one curve and the number of bacteria normally present by another, the two curves would in general parallel each other. Beginning at the mouth, they would rise rapidly, attaining a maximum in the pharynx, would then descend in the region of the esophagus and

stomach, beginning to rise again in the small intestine, gradually approaching another maximum about the ileo-caecal valve, then descending in the lower colon, where many of the bacteria die. In the throat, the tonsils represent the greatest single accumulation of lymphoid tissue, while in the intestine the agminated follicles of Peyer and the appendix represent the same. The significance of these accumulations appears to be that of a protective mechanism against various intestinal substances, bacterial and otherwise.

I will point out here that lymphatic glands are recently acquired structures phylogenetically, being apparently limited to birds and mammals. Tonsils are even more recently acquired, many mammals like the rat, beaver, porcupine, bat and some others not possessing them. There is good reason to believe that bacteria and infectious disease in animals preceded the phylogenetic development of lymphatic structures, so that the view is suggested that this striking distribution of lymphatics in the body, and especially in the intestinal canal may have been determined by the bacterial distribution; which distribution in turn was primarily determined by the anatomical and physiological conditions.

Now in these two lymphatic maxima not only is the normal bacterial flora more highly developed, but here occurs the greatest number of infections. In the throat, streptococcus, pneumococcus, meningococcus, staphylococcus infections, diphtheria, the viruses of numerous exanthemata and other diseases; in the lower intestine and colon, typhoid, paratyphoid, dysenteries, tuberculosis, appendicitis, etc. In the intervening localities relatively few infections occur. The pathogenic organisms often invade primarily the lymphoid structures themselves or the parts rich in lymphoid tissue. In other words, it would appear that in some instances at least organisms become adapted to grow in lymphoid tissue, that is, they attack the very mechanism which the body has apparently designed to protect itself against them. A striking example of this are the hemolytic streptococcus infections of the tonsil. These are acute inflammations of this organ, involving the surface and the crypts and are definitely contagious. The infection is limited quite strictly to the tonsil and is caused by a streptococcus called hemolytic because it has the power to lake red blood corpuscles. The transmission is direct normally through droplets or contact (hands, kissing, tableware, etc.). Another variety of this infection is septic sore throat, which is very severe as a rule. Here the tonsils are infected by streptococci that find their way into the milk either from a person handling the milk or from a cow whose udder has been infected and then serves as an incubator for these organisms. Some years ago we were able to show in our laboratory

experimentally that cows might become carriers of these human hemolytic streptococci when injected into the udder. It is an interesting fact that these streptococci have such a specific affinity for the human tonsils. Between thirty and forty epidemics of this kind of sore throat have now been reported, all traced to milk as a source.

The above observations are quite in accord with a pathological principle more or less general which reveals strikingly the adaptation that continually is taking place between our bodies and bacteria. Other examples may be noted. In typhoid fever, the bacilli primarily attack and invade lymphoid tissue in the bowel and in other parts, and as Mallory has shown, the characteristic lesion in this disease is a proliferation of endothelial leucocytes generally. It, perhaps, would be more proper to speak of typhoid, therefore, as an infection of the lymphatic system rather than an intestinal disease, the intestine simply being the portal of entry. It is another example of a germ having adjusted itself to grow on and invade a protective mechanism; and even though the organisms are always generally distributed rarely localize elsewhere than in lymphoid structures. The same principle is involved in the formation by staphylococci and streptococci of specific substances which will destroy those important defensive cells in our bodies, the leucocytes. These substances are called leucocidins. These bacteria have specialized in the formation of a definite substance which destroys one of our most important defensive mechanisms.

Lymphoid tissue thus may not be equally protective against all bacteria, and in certain infections this mechanism breaks down entirely and instead of being protective it furnishes a fertile soil for growth of bacteria and a route for invasion. The germs may directly attack this tissue and successfully thrive there at least for a time until the body can marshal defensive mechanisms of another order. It is on account of the prevalence of certain infections in this tissue that it may be to the advantage of the body to remove this mechanism or a part of it as is done in tonsillectomy for the prevention of recurrent tonsillitis, or in appendectomy to prevent recurring appendicitis, etc.

A point of importance in connection with tonsil infections is the surface area involved, since this is one factor in determining absorption of organisms and their products. The epithelial surface of the tonsils is many times increased on account of the branching pockets or crypts penetrating deeply into the organ. We have attempted to measure this total surface and find that roughly in an average tonsil of 2 x 1.8 x 1 cm, the entire epithelial surface would amount to about 25 sq. cm, a surface of 5 cm on a side, or roughly

eight times the exposed tonsil surface. Tonsils vary markedly in size, as do also the number and size of crypts; in hypertrophied tonsils, the surface would be far greater than this. Furthermore, the epithelium lining the crypts is loose and spongy, the round cells penetrating the layers even to the surface giving rise to the well-known epithelial structure of the crypts, interpreted and spoken of as a physiological wound. Here, then, is a surface enlarged by invagination and exquisitely designed for absorption. While the extent and nature of the surface are important factors in any infectious process, it should be said that it is not usual for all parts of the tonsils to be equally involved. Individual crypts in a given tonsil vary in the number and kinds of bacteria therein. Some may be nearly sterile, others contain many organisms. In microscopic sections of diseased tonsils certain parts of the organ or more often certain crypts may show marked exudation and change, while other parts or crypts in the same organ may reveal little or no significant alterations.

The distribution of plasma cells in the body is suggestive in connection with infections of lymphoid tissue and especially the tonsils. Generally speaking, these cells are indicative of chronic inflammation or irritation, and most writers regard them as pathologic cells, at least when found in appreciable numbers. They accumulate in masses about centers of chronic inflammation and in general are characteristic of granulation tissue. They appear in many low grade inflammations of the skin and mucous membranes.

The tonsils and crypts become infected by bacteria at birth or within a few hours thereafter. Even pathogenic organisms very early appear, streptococcus pyogenes having been noted as soon as ten hours after birth. The flora of the infant mouth is largely streptococcal.

Using the local accumulation of plasma cells as a possible criterion of the absorption of bacteria or their products, I studied the time of appearance and the distribution of plasma cells in tonsils. Two hundred and forty pairs were examined for these cells. One hundred and eighty pairs were extirpated from children and adults and about sixty pairs came from autopsies on subjects of various ages ranging from fetuses to the very aged. Seventeen were from infants less than three months old.

The results briefly were as follows: These cells are not found in the foetus or the new born. They make their appearance regularly about the second or third week, and are always found thereafter. In children several months old they are constantly found and usually in abundance. They remain present throughout life and even to very old age (88 years) regardless of the anatomic

condition of the tonsil. In pathological tonsils and especially in hypertrophy they are very numerous. They occur under the epithelium of the crypts along the strands of connective tissue and clustered about small blood vessels.

In view of the rôle that these cells play in general pathological processes and since they occur so regularly in tonsils a short time after the entrance of bacteria, one is led to suggest that their presence here indicates a chronic infection focus, where absorption of irritating products is constantly occurring. Aschoff has noted the same in connection with the appendix. Along the entire gastro-intestinal canal, too, one observes large numbers of plasma cells under the mucosa and especially in the region of lymphoid follicles. These facts are quite in harmony with the observations made by Adami and others on the more or less constant penetration of the mucosa by organisms and termed subinfection. No doubt, many bacteria are constantly passing through the alimentary wall into the lymphatics and blood stream, there to be disposed of in different ways. To these bacteria and their products after penetrating the epithelium the plasma cells probably offer the first barrier or line of defense. In the sense, therefore, that the term subinfection has been used in connection with the condition of the so-called normal tonsil, or in the sense in which Aschoff uses the term chronic inflammation in the appendix, so we may regard all tonsils as chronically inflamed a short time after birth. One should, however, interpret such findings in tonsils rationally, and when the terms are used as above they should not necessarily convey the idea of a dangerous or serious pathological state requiring surgical intervention. Nor should they be interpreted as a focus of infection in the sense in which that term is now commonly used.

It became quite evident from some of our earlier studies that more information concerning the pathology and especially the bacteriology of the tonsil crypts should be obtained, and to this subject in our laboratory more recently our attention has been given.

The statement is often made that the flora of the tonsils and the crypts is abundant and varied. This does not appear to be true or true only in a certain sense. By no means will any or every germ that enters the tonsil crypts live and develop there. To determine this, we tested the viability of a number of organisms in the crypts. After first making careful cultures of a crypt for control purposes, a few drops of a live bacterial suspension were injected into it by means of a curved blunt needle. The crypt was then daily cultured. The bacillus prodigiosus after injection gradually became less numerous and at the end of the fourth day had completely died out. *B. pyocyaneous,* a pathogenic chromogen, after injection

caused a slight reaction in the throat lasting a day or two. The organisms gradually became less and by the fifth day had disappeared. *B. coli* will likewise disappear in the course of two days. It is evident from these data that certain bacteria, even those well adapted to grow in certain parts of the body, will not flourish in the tonsillar crypts. In other words, it is not proper, as has been done, to look upon the tonsil crypts as a cluster of media tubes set in the upper part of the alimentary canal growing numerous varieties of bacteria and discharging them into the lumen. As we shall see, the flora of the tonsils is a highly specialized one, restricted quite definitely to a few varieties.

Some years ago, when studying the bacteriology of extirpated tonsils from certain cases of chronic infection, I noted a striking difference between the surface flora and the crypt flora of tonsils. On the surface the predominant organisms were of the streptococcus viridans type, whereas the predominant organisms in the crypts of the same tonsil were as a rule hemolytic streptococci. The exceptions were few. The difference was so striking that at first I attributed great significance to this point, since the hemolytic varieties are so much more virulent as a rule than the other varieties. Later I found that most tonsils, regardless of the associated condition, contained a similar flora. Hypertrophied tonsils, especially, but also others that show no noteworthy pathology reveal the same distribution of the varieties of streptococci on the surface and in the crypts. Pilot in our laboratory recently also examined one hundred tonsils after removal, extirpated chiefly for hypertrophy, though many were normal in size, and found on the surface hemolytic streptococci in 61 per cent. They comprised usually less than 10 per cent. of the total number of bacteria. In the same throats from which these tonsils were removed, cultures taken just before extirpation yielded 43 per cent. positives. Crypt cultures, however, from these same tonsils yielded 97 per cent. positives and in almost all the hemolytic variety was greatly predominant. Furthermore, in another series of twenty-four normal persons cultures from the throat and pharynx in 58 per cent. yielded hemolytic streptococci, and in 19 persons without tonsils cultures similarly made yielded them in 15 per cent., and in these persons were found either bad teeth or tonsil remnants.

It appears from our results that the crypts are an almost constant source of hemolytic streptococci, and this location may be considered in a way their normal habitat. We have not been able to find any other part of the body that so constantly harbors them. The throat, as we have known for a long time, is their chief source and habitat in the body, and it would now appear that it is the

crypts of the tonsils which usually supply the throat with these organisms. From the throat they may be distributed to various parts of the body by contact and otherwise. Or they may be transferred to other persons through the usual channels of transmission of respiratory diseases. In this connection, this point deserves emphasis. Nearly every one is harboring hemolytic streptococci in the tonsils which have not been differentiated from strains that cause serious infections, pneumonias, etc. Some of these strains are less virulent, but not all. Presumably such bacteria may or may not cause arthritis, iritis and other so-called focal infections, but finding them in the tonsil may mean nothing in relation to a possible systematic disease. Should one find abscesses or other definite pathologic lesions in the tonsils, a bacteriologic examination may be of value in determining the cause of an associated condition.

From the anatomic structure of tonsils, one might expect organisms requiring varying degrees of oxygen tension to thrive there. and this leads us to a discussion of certain organisms which grow better in the absence of oxygen, namely, the anaerobes.

There exist frequently in the tonsils peculiar granular bodies. At some time or other they probably occur in the tonsil crypts of every one. They are cheesy-like particles, foul smelling, small gray or yellow, single or more often multiple, lying in the crypts, never in the tissues proper. On microscopic section, they are seen to be made up of filaments arranged in ray-like fashion, suggesting actinomyces. These structures are remarkably uniform. On analysis, they are seen to be composed of four kinds of organisms evidently growing together in symbiosis, namely, leptothrix, fusiform bacilli, spirochaetes and streptococci. The leptothrix grows under anaerobic conditions and in the crypts develops into a cluster of filaments some of which radiate to the periphery, forming central stalks about which fusiform bacilli are arranged perpendicularly, closely resembling the structure of a test tube brush. Scattered throughout this growth are very large numbers of spirochaetes and streptococci. The streptococci in these masses have recently been studied in detail by Pilot and the writer. They are both hemolytic and non-hemolytic. The hemolytic are aerobic and quite like the varieties that occur commonly in the throat. Many of the non-hemolytic streptococci are distinctly anaerobic when first cultivated. They exhibit a green halo on blood agar plates and if the initial cultures are not made anaerobically they will not appear. After a few transplants under aerobic conditions, however, they will adapt themselves to grow well and soon equal the anaerobic growth. This anaerobic property of the green strains is very definite and is readily discernible in the first series of cultures. They are not

highly virulent for rabbits, being comparable in this respect to the ordinary streptococcus viridans of the buccal mucosa.

On the teeth along the gum margins appear constantly similar radiating growths made up of the same four varieties of organisms. They compose a considerable part of the tartar on the teeth. When removed, the growth returns again in two or three days. In the lower intestinal canal and also about the genitals are two other sources of these organisms where at certain times they thrive abundantly.

Having considered briefly the normal habitat and distribution of these organisms, I will now say a few words about their relation to disease. These organisms are opportunists and like other germs about the body will, under certain conditions, cause serious infections. The conditions under which they do this are manifold. They are prone to develop in tissues which for any reason have lost their vitality, for example, in persons who have suffered from other diseases and especially when tissues have been injured by wounds, foreign bodies, vascular changes, tumors, severe infections, anesthetics, etc. So as a result of the growth of these germs, especially the spirochaetes, fusiform bacilli and streptococci, there arise infections about the throat like Vincents angina, gangrene about the mouth or face called noma, growths on the tonsils known as pharyngmycosis, putrid infections of the middle ear, and various lung infections characterized by a very foul odor of the breath and sputum like pulmonary abscesses, putrid bronchitis and empyema. In the intestinal canal, also, similar putrid infections arise sometimes, causing appendicitis and colitis; and about the genitalia at times serious gangrenous lesions arise as a result of infections by these same organisms which, as before stated, often occur normally in these localities.

In conclusion, I wish to say a few words more specifically about the prevention of tonsil diseases. Operation on the tonsil is nearly always the simple removal of the organ and is done for *preventive* purposes, in contrast, therefore, to so many operations whose primary purpose is curative. When the indications are clear it is one of the most logical and satisfactory procedures. Acutely diseased and highly inflamed tonsils are not removed, the operation being postponed until the inflammation subsides.

The clearest indication is recurrent tonsillitis, serious enough in itself but so often leading sooner or later to arthritis and to other diseases, especially the heart. Chronic infections which we now speak of as focal infections are clear indications, when it can be determined that the tonsils are the source of the trouble. But I may say that many of these cases present diagnostic problems of the very greatest difficulty.

Acute articular rheumatism is nearly always primarily a tonsil problem, and the indication is clear for tonsillectomy, especially after the first attack. Many workers believe children's diseases, like scarlet fever, measles, etc., are not so severe or complications are less apt to follow in those whose tonsils are removed. It has been found too that in diphtheria carriers enlarged and diseased tonsils occur in a large percentage.

With reference to the fuso-spirochaete-streptococcus combination in the tonsils and about the teeth, since we now know more about their haunts, we should expect to be able to formulate a more rational prophylaxis. While it may be out of the question completely to disinfect the mouth or the tonsils, the number of bacteria harbored there may be greatly reduced by various procedures. In dealing with organisms of this type, diminishing the dosage of bacteria generally is an important element in prevention. Removal of the tonsils and drainage of the crypts containing these granules are rational procedures to pursue relative to the hygiene of the tonsil. Thorough and frequent cleansing of the teeth, especially between them and about the gums, removal of tartar and of pus pockets, and in general the establishment of a clean normal healthy mouth and throat would clearly be indicated in this connection. Especial precautions should be exercised in persons about to undergo anesthesia for any purpose, but especially in tonsillectomy or other operations about the mouth or throat where danger of fuso-spirochaete lung abscess and pneumonia exists.

One may well ask if there is not a single good word to say for the tonsils. One of the best tests both of the function of any organ and also its relation to disease is to remove it in a very large number of cases and observe the result. This has been done with the tonsils. A few writers have thought that in those whose tonsils were removed early in life an adenitis was more prone to develop. Digby especially has tried to make out a case for the tonsils and subepithelial lymphatics as tissues that primarily are concerned with establishing an immunity in health, which appears to be a very plausible assumption. But even so, the tonsils are relatively so insignificant in comparison with the very large amount of lymphatic tissue in the throat that its absence would probably not materially affect this process, assuming that it occurs.

On the whole, data of this character are meager in comparison with the overwhelming evidence that it is possible to array against the tonsils as dangerous foci of disease. It is about as difficult to defend them on the grounds of usefulness as it is to defend the appendix. It appears from what we now know that if we were born without tonsils and appendix, we would lose nothing, and the risk

of living would be materially diminished. Removal of the organs apparently accomplishes this purpose, but, of course, dangers of operative procedures must be considered. Complications may result occasionally, such as hemorrhages, lung abscesses, post-operative pneumonia, etc., but such accidents are subject to control and should be very largely eliminated by care and further research.

It should be realized that the safest position for the medical man to assume with respect to operations in general and especially with respect to the removal of organs is that of a progressive conservatism. It is safer to act upon clear indications when they arise, even though occasionally the consequences may be serious, than to indulge in the more or less wholesale removal of organs, whatever may be their supposed function.

WILHELM HOFMEISTER

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Of all the great men of botany in the nineteenth century the career of Wilhelm Hofmeister was the most phenomenal. Without a university training, without the help of a teacher in research, he lifted himself into recognition as one of the foremost men of science of his time. Without previous university connections, he was advanced by a single step from the status of a tradesman to that of a professor of full rank in the University of Heidelberg—the oldest university of Germany. This was a tribute to the extraordinary attainments of the man.

In view of his great eminence, it is difficult to account for the scarcity of biographical sketches and "appreciations" of Hofmeister. At the time of his death, in 1877, the scientific periodicals contained only brief notices of his life and botanists of to-day have found difficulty in locating a satisfying sketch of Hofmeister and his labors written by one of their own craft.[1]

Since he attained such eminence the facts about his education, his worldly circumstances, his advantages and limitations of environment, the conditions under which he did his work, etc., acquire an especial interest. Hofmeister was essentially a self-made man; no especially favorable circumstances were responsible for his advancement; he was not the product of his environment but of his heredity. He was gifted with a penetrating mind, he showed great capacity for work, fixedness of purpose, and apparently reached many of his conclusions by the "intuition of genius." One circumstance that doubtless favored his output was the love and congeniality in his home life.

In the account of his life which follows I have drawn largely on the narrative of Pfister, who obtained many of his facts from the Hofmeister family.

Wilhelm Friedrich Benedikt Hofmeister was born in 1824, at Leipzig, where his father was a highly respected bookseller and

[1] A sketch of Hofmeister, with portrait, was published in *The Plant World*, 1905. This was a translation from the German of Professor Göbel by Professor Francis E. Lloyd. The most comprehensive memoir on Hofmeister and his scientific work is by Ernst Pfister in "Heidelberger Professoren aus dem 19 Jahrhundert," Vol. 2, pp. 267–378. For portrait different from that in *The Plant World*, see "Acta horti Bergiani," Vol. 3, and Fig. 135 in the writer's forthcoming book "The Growth of Biology."

occasional publisher. He inherited from his father an interest in botany and from his mother a keen mind. His earliest instruction outside the home was in a private school, from which he entered the newly-founded Realschule of Leipzig. This institution had been established in 1834, by Dr. Karl Vogel, a friend of the elder Hofmeister. Vogel was a competent teacher, with fresh ideas of education, and emphasized a kind of mental training that led students to think for themselves. In 1839, at the age of fifteen, Wilhelm Hofmeister left the Realschule and ended his education under the direction of masters. His further attainments were the result of self-education; but it must be remembered that he was especially acquisitive and original. He immediately reviewed the principal subjects he had pursued at the Realschule (physics, chemistry, algebra, trigonometry, geography, etc.) and added to them. He lacked the much valued classical training of the German Gymnasia, but the powers of his mind had been improved by methodical training in those subjects which he had pursued at Vogel's Realschule. Having a natural taste for music he learned to play the violin without a teacher and he began to take an active interest in the study of plants and insects, stimulated thereto by his father and some of his learned friends.

In the summer of 1839, just after leaving the Realschule, he entered the musical establishment of Cranz at Hamburg as "Volentar"—an apprentice or unsalaried clerk. This has given rise to the statement in some cyclopedias (Britannica, etc.) that he was by occupation a music dealer—this connection, however, was only a temporary venture engaged in between the ages of fifteen and seventeen. From the age of seventeen, for 22 years (1841-1863) he was in his father's bookselling establishment at Leipzig. The article in the New International Cyclopedia says he was a "druggist," but of this I find no authentic record. At Hamburg, his mornings were relatively free and he employed his time in a review of his previous studies, in taking lessons on the violin and in excursions on foot and by boat in the vicinity of Hamburg.

In 1840, Hofmeister's father acquired a property at Reudnitz in the suburbs of Leipzig, comprising a house and a garden in which he arranged plants according to the natural system. At first the house was used as a summer residence, but was soon converted into a family dwelling occupied by the parents, their children with their families, and for some time four families of Hofmeisters lived happily and in harmony at this parental domain. Here Wilhelm Hofmeister brought his wife in 1847; here were born five of his children, and here he carried on his investigations and prepared his monumental publications. In 1841 he entered his father's

firm as foreign correspondent and was connected with the business until his call to the University of Heidelberg, in 1863. At first he had some leisure to devote to his studies, but very soon, the business at the Leipzig store so occupied his time, that, as he himself said, his only regular working hours in science were from four to six o'clock in the morning. In the Hofmeister household, love, congeniality, simple living and high thinking prevailed. The families living there had friendly social relations with a few kindred spirits of learning and culture, and all this was helpful to the development of Wilhelm Hofmeister. He had formed a friendship with Professor Reichenbach, of Hamburg, who encouraged him. He was also greatly influenced by reading Schleiden's "Outlines," which directed his attention to microscopic botany and to the embryology of plants. In this field of work his extreme nearsightedness was not a handicap but in some ways an advantage in the handling of minute objects and in making thin sections for the microscope. It speaks well for his sharp mental discrimination that, at this early age, he pronounced the work of von Mohl of higher quality than that of Schleiden.

In 1847 he was married; the same year he published a scientific paper, the next year another one, and, in 1849, there appeared his first work of commanding importance, the treatise on the origin of the embryo of Phanerogams, published as an independent brochure by his father. This work attracted such wide attention in the scientific world, as well as among botanists, that, in less than two years after its publication, the University of Rostock conferred upon him the degree of Doctor of Philosophy *honoris causa,* thereby extending the first formal recognition from the university world of his high standing as an investigator. The Royal Saxony Society of Science, at Leipzig, elected him to full membership.

He was now working with intense application, and in 1851, his father's firm published another independent work. This was his famous path-making treatise entitled "Comparative researches on the germination, development and fruit-formation of the higher cryptogams and on the seed-formation of the conifers." This was the high-water mark of his achievements—a research so brilliant that it led von Sachs in his history of botany to exclaim: "The results of the investigations published in the *Vergleichende Untersuchungen* in 1849 and 1851 were magnificent beyond all that has been achieved before or since in the domain of descriptive botany; the merit of the many valuable particulars, shedding new light on the most diverse problems of the cell-theory and of morphology, was lost in the splendor of the total result, which the perspicuity of each separate description revealed to the reader before he came to the

conclusion of the work, and there a few words in plain and simple style gave a summary of the whole." The significance for botanical science of these two works will be spoken of later. The treatise of 1849 was dedicated to Hugo von Mohl, that of 1851 to "*Seinem treuen Vater in Liebe und Dankbarheit*," which reminds one of the famous filial tribute of Pasteur in the dedication of one of his chief works to his father.

After 1851, as products of his great activity, researches along the same general line continued to appear and his friends began to fear that he would break down under the strain of business cares and activity in research. Then came, in 1863, a signal recognition of his distinguished services to the progress of scientific botany; this was an invitation to accept the professorshp of botany in the University of Heidelberg. It is to be remembered that the practice and traditions of German universities were so conservative that, except in the Faculty of Medicine, it was unprecedented for a man without previous university connections to be called to a professorship. Hofmeister had never even attended a university and from the age of fifteen to thirty-nine had been engaged in trade. These factors were against him, and it was purely on the basis of extraordinary merit that he was seriously considered for the position. Hofmeister was not nominated in the usual way by vote of the philosophical faculty, but owed his nomination to the Grand-Ducal Ministry of Baden. In 1854 Professor Reichenbach died at Heidelberg, and the philosophical faculty named von Mohl as its choice to succeed him. Owing to circumstances, however, the call was not made, and in the interim the position was held by the adjunct professor, Anton Schmidt. In 1861 members of the faculty took a new vote and named de Bary as their choice, but this action did not result in a call. In May, 1863, the Grand-Ducal Ministry said to the faculty, if their vote of 1861 was not carried out, that the ministry would nominate Dr. Wilhelm Hofmeister for the position. They spoke of their candidate as follows: "He impresses us as one of the foremost botanists of Germany, as a man of genial disposition, of great technical skill and active productivity, who for the first time shows an inclination to accept an academic position, and also at present has the certain prospect of a call to Hamburg." Notwithstanding some misgivings expressed by the faculty, he received this appointment, and, in the fall of 1863, moved with his family to Heidelberg, entering the university with full rank as Ordentlicher professor of botany and director of the botanical garden.

From the accounts of Goebel and Pfitzer, two of his botanical contemporaries, Hofmeister was a likable personality, alert and interesting. "His appearance had in it nothing of the German

type; he looked like a southern Frenchman. Of small supple form, he possessed a dark, clear-cut and uncommonly vivacious face; he was always bubbling over with activity and ever showed great kindness to his students."

As a lecturer in the university, Hofmeister overestimated the state of preparation as well as the earnestness of general students of science, and placed his lectures on so high a plane that he emptied the benches of his lecture room of the miscellaneous students in pharmacy, in pre-medical studies and in general science, but he held the attention and secured the admiration of the more advanced and serious-minded. Among the men who worked under him, either at Heidelberg or at Tübingen, we find the names of Askenasy, Engelmann, Goebel, J. Knauth, Krutitzky, Millardet, N. J. C. Müller, Pfitzer, Rosanoff and Zacharias.

He was especially expert in laboratory instruction and made before his students microscopic preparations of remarkable fineness. With his colleagues on the faculty he showed himself a good companion, a ready and interesting talker of wide intelligence, and made many personal friends. Owing to a variety of small causes involving differences of opinion the faculty at Heidelberg became divided into two camps; Hofmeister had friends in both, and being too sincere to dissemble, his friendships became strained in some quarters, and his life there was made unhappy. He was further distressed by sickness in his family, and within a year suffered the grief of losing his wife and youngest daughter by tuberculosis. He was now (1872) called to Tübingen to succeed Hugo von Mohl, and gladly accepted this opportunity for change of environment. Having been at Heidelberg nine years, he was destined to hold the professorship at Tübingen for only four years, and thus ended his entire university career within thirteen years. His two favorite sons, aged, respectively, twenty-three and twenty-five, died of tuberculosis, both in 1875.

In 1876 he himself suffered a stroke of apoplexy and was obliged to resign from his professorship; he passed away at Leipzig in 1877.

We come now to consider Hofmeister's scientific publications and their influence on botany. There is a marked unity of purpose in the rather numerous scientific memoirs of Hofmeister. They are not disconnected pieces of work, containing discoveries of miscellaneous facts, but for the most part they form a series of program-studies extending over a number of years, and directed towards the solution of definite problems.

In 1847, he began a series of publications which extended to 1860, on the origin of the embryo of the flowering plants, including fertilization of the egg and formation of the embryo. The first of

these papers to attract wide attention was published in 1849, on the origin of the embryo in the Phanerogams. This paper with the German title "Die Entstehung des Embryo der Phanerogamen," occupies a central position in the series on the embryo of the Phanerogams. It is a famous botanical document, published as a separate work of 89 quarto pages, and 14 copper plates embracing not less than 429 figures.

There is a characteristic directness about Hofmeister's style which requires close attention in reading. His writing is dignified, straightforward, and impresses one with the remarkable clearness and certainty of his observations. His brief critical remarks are in marked contrast with the boastful and exaggerated tone of Schleiden.

The work of 1849 starts abruptly with a description of observations and without any preliminary remarks. At the end there are nine pages of a clear and concise summary and conclusions in which he shows that the 38 plants of 19 genera examined all agree in essential features as to their method of fertilization and embryo formation, and he expresses the belief that these phenomena are the same for all phanerogams. The facts assembled in this paper undermined the pollen-tube theory of Schleiden, and in 1855 he published decisive researches which accomplished the complete overthrow of Schleiden's contention. About 1840, one of the questions that vexed the botanical world was the origin of the embryo in plants. Schleiden maintained that the embryo arose from the tip of the pollen-tube—thus making the embryo-sac a nidus within which the end of the pollen-tube was nourished into an embryo plantlet. Hofmeister showed that the pollen-tube carries elements of fertilization and that the embryo is formed from an egg-cell already existing within the embryo-sac developed within the ovule. He traced the origin of this egg-cell showing that a substance carried by the pollen-tube fertilizes the egg, and how the embryo develops within the ovule out of this fertilized egg.

In these observations he had been in a way preceded by Amici and Robert Brown, but Hofmeister's observations were so extensive and exact that Schleiden's observations on these points and his theory of formation of the embryo were set aside. Hofmeister not only traced the origin of the egg within the ovule, but also showed the development cell by cell of the embryo.

The work published in 1849 on the embryo of the flowering plants was merely the starting-point of a larger enterprise. Already, before its publication, Hofmeister was engaged in similar investigation of the lower plants. Although some of the main facts in the life-history of ferns and mosses had been made known, the crypto-

gams had been quite generally neglected in botanical investigations. Ignorance of cryptogamic botany was, indeed, the chief cause for the long delay in discovering a unity of relationship throughout the vegetable kingdom. Hofmeister made his studies comprehensive, including the lower as well as the higher plants, and he erased the line of demarcation that was supposed to separate the cryptogams and the flowering plants.

From his comprehensive studies there resulted "that great general pronouncement" first published in 1851—the most remarkable single piece of scientific investigation of the period—a work which F. O. Balfour says "will always stand in the first rank of botanical books." Its long title, however, is not alluring: "Vergleichende Untersuchungen der Keimung, Entfaltung und Fruchtbildung höherer Kryptogamen und der Samenbildung der Coniferen," a book of 179 quarto pages and 33 copper plates, published in Leipzig by his father's firm. After its publication there followed a number of further researches along the same line, extending his observations to other plants and making clearer and fuller his conclusions. At the request of the Ray Society of London, he combined his various researches of this nature into a uniform whole, "revising the text throughout and adding a quantity of matter existing in manuscript." This assembled product appeared in English translation in 1862, under the title: "On the Germination, Development and Fructification of the Higher Cryptogamia, and on the Fructification of the Coniferae." The original publication of 1851 is difficult to obtain, and I have been obliged to use only the readily accessible English translation. It is more extensive than the original in 1851, making a volume of 491 octavo pages of text, with 75 plates and more than 1,100 figures.

By extensive observations Hofmeister demonstrated the existence of an alternation of a sexual with an asexual generation in all plants, from the lowest to the highest, which made necessary some sort of theory of their community of descent. These two points require some further elucidation.

The term, "alternation of generations," had been introduced into biology by Steenstrup, in 1845, to apply to those cases in animals where a generation arises by budding from parent-forms which is very different in appearance from the parents, and this generation, in turn, gives rise by a sexual process to the parent-form. This is well illustrated in the hydroid polyps, where a colonial branching form sets free by budding, medusoids which as independent jelly-fish swim freely and lead an independent existence. This generation of medusoids produces eggs and fertilizing agents, and their offspring resemble the original parent form, but

not at all the generation of beings from which they have sprung. The alternation of generations in plants is only generally similar to this process, but it extends to them all. By the germination of the spores of ferns, for illustration, there arises a plant which produces the sexual elements and from the union of these there develops a generation similar to the original plant. Furthermore, this phenomenon, although obscured in the higher forms by the production of seeds, is common to all plants. Says Goebel, in 1905, "This is, in very truth, the greatest discovery that has ever been made in the realm of plant morphology and taxonomy."

Another sweeping conclusion resulted from Hofmeister's "Comparative Researches"; they revealed all plants as genetically related; no longer could individual plants be looked upon as separate creations, or entities; the lower forms were shown, by their structure and method of development, to merge into the higher forms making a unified series. Thus, almost automatically, the conception of the community of descent of plants took its place. This interesting fact is of historical importance in connection with the rise of the theory of organic evolution. In 1851, fully eight years before the publication of Charles Darwin's "Origin of Species," a theory of community of descent of plants had been made necessary by the illuminating researches of Hofmeister. Darwin's publication made it general, and, after 1859, it applied to both animals and plants.

How directly Hofmeister arrived at his points is shown by his giving (in the English translation referred to) only eight pages of review and general conclusions, after 433 pages of scientific results. Hofmeister is not confused by the often perplexing conditions brought out by his researches on individual plants; with remarkable clearness he picks out the corresponding processes; he shows that a uniformity exists between the fruit-formation of mosses and the embryo-formation of higher cryptogams, and that the formation of the embryo of gymnosperms is intermediate between the higher cryptogams and phanerogams. In the cryptogams the fertilization is accomplished by free swimming spermatozoa, in the conifers and angiosperms by a pollen-tube, within which non-motile spores arise and effect the fertilization.

Here, by the phenomena of similarities in respect of fertilization, fruit-formation and embryo-formation, all plants from the lowest to the highest are united into an unbroken chain. Hofmeister says: "The phanerogams therefore form the upper terminal link of a series, the members of which are the Coniferae and Cycadeae, the vascular cryptogams, the Muscineae, and the Characeae. These members exhibit a continually more extensive and more independent vegetative existence in proportion to the gradually descending rank

of the generation preceding impregnation, which generation is developed from reproductive cells cast off from the organism itself."

After going to the University of Heidelberg, Hofmeister published, in 1868, his "Algemeine Morphologie," introducing into morphology a new conception somewhat similar to the experimental morphology that in later years was extensively developed by zoologists. But the idea of Hofmeister of the dependence of plant organization on inner and outer conditions has, as Goebel suggests, been too little followed up by botanists.

He projected a handbook of plant physiology with the collaboration of de Bary, von Sachs and several other botanists of high standing. Hofmeister was designated as editor, and, although he supplied and published most of his share, the enterprise as a whole was never completed. In addition to the works mentioned he published an excellent treatise on "Lehre von Pflanzenzelle" and some observations on the physiology of plants. Out of his whole scientific product the publications of 1849 and 1851 stand forth in relief as the best known and as containing his most notable and fruitful work.

Hofmeister's discoveries and conclusions changed the outlook and entered largely into all future progress of botany. Besides his many individual contributions to the knowledge of plants he will be remembered for three outstanding generalizations:

(1) He demonstrated the true nature of fertilization in flowering plants; observed the origin of the ovum and the formation of the embryo cell by cell. These results were published in 1849.

(2) In 1851 he published his observations on the fertilization and fruit-formation of higher cryptogams and the conifers, connecting these results by broad comparisons with his observations on the angiosperms. This publication embraced the discovery of alternation of generations throughout the vegetable kingdom.

(3) His comparative studies made necessary for all plants a theory of community of descent.

After Hofmeister we enter the modern era of plant study and, since no one except a professional botanist can adequately write the history of its more recent developments, this is a convenient point to leave the story of the growth of biology from the botanical side. There remains, however, certain advances of the nineteenth and twentieth centuries that are broadly biological. Such topics as the cell-theory—the result of the work of both botanists and zoologists—and the rise of a separate division of biology, named cytology, belong to this category; also such general advances as the experimental study of heredity and discovery of the laws of inheritance.

These experimental studies, first (or at least very early) carried out by Mendel on plants, became the starting point, at the opening of the twentieth century, for active investigation of both botanists and zoologists, and gave rise to the subject of genetics. Furthermore, the work of Pasteur was so broadly biological in character that in following it up, botanists and zoologists were drawn into one circle of investigation. The doctrine of organic evolution, in which Hofmeister was a pioneer on the botanical side, is likewise a field where botanists and zoologists met on common ground.

PROGRESS IN METHODS OF INQUIRY AND RESEARCH IN THE SOCIAL AND ECONOMIC SCIENCES

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THE object of this paper is to critically examine methods of research used in the social sciences. The term "social sciences" is here used to include economics, political science and sociology. Results of research will be mentioned only as they illustrate advances in method. Since the subject-matter of the paper must of necessity be somewhat abstract in nature, it may be helpful at the outset to outline the manner of treatment. The method of scientific induction will first be considered. Difficulties in the use of scientific induction in the social sciences will next be considered. There will follow a discussion of specific ways in which these difficulties have been or may be overcome by the use of three methods of social research. The relation of the three prevailing methods of social research to the scientific method will then be considered and, finally, some of the typical organized agencies conducting scientific research will be mentioned.

Pearson[1] has made the point that whatever may be the diversities in subject-matter of the different sciences, the scientific method is always and everywhere the same. If this be true, then there must be some simple skeleton of procedure back of and common to such variations in scientific method as are commonly indicated by the terms experimental, analytical, statistical, synthetic, inductive, objective, deductive, classificatory or descriptive method.

THE METHOD OF SCIENTIFIC INDUCTION

The following formulation of scientific method into four consecutive steps has been useful to me as a test of scientific research:

First step: formulation of a working hypothesis of investigation.
Second step: collection and recording of the facts of observation.
Third step: classification of the facts of observation.
Fourth step: generalization from the facts of observation.

This enumeration of the steps of scientific inquiry also embraces all the variations in method mentioned in the preceding paragraph,

1 "The Grammar of Science," 2nd Ed., 1892, p. 6.

or more specifically: observation should be analytical and descriptive; the experimental method is merely observation made under conditions of control; measurement of the phenomena observed should be in objective terms or units; classification is partly an analytical and partly a synthetic process; the series of steps is itself a statement of the inductive method; the use to which the final generalization or law is put in explaining some particular occurrence is deduction, and deductions from inductive generalizations established in this way form the reliable predictions of science.

Social scientists have been justly criticized for not using this method of scientific induction and for over-fondness of making deductions from hastily formulated hypotheses that have never been subjected to the test of sufficient facts of observation. Critics have held that, so long as social scientists were content with semi-philosophical generalities based upon impressions rather than upon facts of observation, their fields of study could not be regarded as organized scientific knowledge, but that as soon as scientific induction, in contrast to speculation and empirical thinking, was adopted, scientific progress would result. Social scientists have certainly not been unacquainted with scientific induction; yet they signally failed in its use. This failure appears to have been due to certain logical pitfalls that have not been avoided. Let us consider briefly these pitfalls, step by step.

In the first place, working hypotheses are often suggested by analogy, although analogies are proverbially dangerous in scientific work. It has often been forgotten that an hypothesis is a purely provisional formulation, tentative in character and subject to revision by the acid test of facts. Further than this, there has been a tendency to confuse hypothetical units postulated for convenience of analysis with real data of observation.[2] Many economists, political scientists and sociologists have fallen into this logical error when using the term instinct. The term instinct is a word used to describe (among human beings, at least) a hypothetical form of behavior. Many social scientists then pass insensibly to the position of accepting the abstraction itself as datum of observation, although no measurement of the phenomena has been made. The concluding fallacy is to arrive at a generalization based on this false logical process, and to believe that a scientific law has been established.

In the second place, much of the data of observation that has been collected in social science is worthless. The reason is that observations are frequently recorded in subjective or in qualitative terms. To be of scientific value, observations must be recorded in

[2] Faris, "Are instincts data or hypotheses?" *Amer. Journal of Sociology*, Vol. 27, No. 2, pp. 184–96.

objective and, if possible, quantitative terms. Moreover, little effort has been made to discriminate between compensating and cumulative errors of observation.

In the third place, the act of classifying has been performed as though it were an end in itself. The result has been that elaborate systems of individual and largely subjective categories of classification have been promulgated. By contrast, the need is urgent for *a posteriori* categories of classification, *e.g.*, of categories that grow out of the common traits of the phenomena studied.

In the fourth place, social scientists have been too prone to easy generalization. I have already indicated in my discussion of the logical pitfalls of hypothesis-making how generalizations based on hypotheses instead of data are confused with true inductive generalizations. The result is seen in the well-defined tendency in much of present economic, political and social theory to refinements of distinction that are of purely verbal character. Finally, one can not help feeling that this prevailing tendency to speculative thought which social scientists "first scorn, then pity, then embrace," is dangerously like the effort of the day-dreamer who seeks in fantasy an escape from a too cruel reality. If *verification* were insisted on in social science to anything like the degree it is in physical science, some of our theorists would have a rough awakening.

But at this point, a word of warning should be said, lest we conclude too easily that the process of scientific thinking is that one perfect thing. It can be shown that speculative thought (running to fantasy and day-dreaming) is not an inherently different kind of thought from scientific thinking, but is only relatively different. Bias is present, or likely to be present, in each step of scientific thinking, for desire determines the selection of memory images that are put together to form the hypotheses; it influences the selection of facts to be observed, the grouping of those facts, the inferences drawn therefrom and also the resulting predictions of future events.[3] Consequently, it becomes a question of continual guard against bias, rather than of taking some formula or thought pattern that will be fool-proof.

Difficulties in the Use of the Scientific Method

This brings us to a consideration of the difficulties of using the scientific method in studying social phenomena. Bias or prejudice is an emotional attitude towards facts or things such that our speculations, observations and inferences are unduly warped from objective truth.[3] Since the subject-matter of social science is not the

[3] Ogburn, "Bias, Psycho-analysis, and the Subjective in Relation to the Social Sciences," Publ. Amer. Sociological Society, Vol. 17, 1922, pp. 62–74.

realm of the inanimate, but concerns human relations, it would seem that bias was peculiarly present, since much of the material with which we deal has highly emotional connotations. Many of our problems go back to questions of sex, of family, of religion, of industrial relations, of wealth distribution and of politics, and all these matters involve strong desires. The great difficulty here is the one of devising objective and, if possible, quantitative methods of observation and analysis, in order that we may accumulate the facts with which bias may be curbed.

The complexity of social phenomena is often mentioned as an obstacle to social fact-getting, but in reality complexity is a blanket term used to cover three special obstacles which are also present in physical sciences—obstacles that the physical scientist has overcome, or circumvented by many ingenious devices of observation. There is not time or space to elaborate this point beyond indicating that the three difficulties, *rarity, subtlety* and *fixity,* that occur in social phenomena, may be dealt with separately, as in the following illustrations:

Of *rarity,*[4] or infrequency of occurrence, says Jevons, "we might wait years or centuries to meet accidentally with facts which we can readily produce at any moment in the laboratories." In social science, we seek control of the economic factor, by minimum wage legislation, or we attempt to control the environment by placing the orphan child in a carefully supervised foster home.

Subtlety of social phenomena often makes them escape ordinary experience. According to Dewey, this quality may appear in the form of minuteness, or violence.[5] In social science, we have learned that the crowd psychology of a financial panic, the psychology of a political upheaval or the behavior of a mob are all merely extreme forms of pluralistic behavior and follow common principles of social psychology.

Rigidity of facts, as we ordinarily experience them in society, often suggest complexity. We see groups and social forms in a state of growth, others in a state of maturity or equilibrium, and others in a state of decay, and do not realize that every group or social form is not rigid, but tends to pass through a cycle of stages of growth, maturity and decay.

Ways in Which These Difficulties Have Been Partially Met and Overcome

There are three fairly well standardized methods of social research:[6] first, the *historical* method of critically using the records

[4] Dewey, "How We Think," pp. 91–93.
[5] *Op. cit.*
[6] Chapin, "Field Work and Social Research."

of past events; second, *field work*, or direct observations of contemporary social phenomena; third, the *statistical* method of quantitative measurement, classification and interpretation by aid of mathematics. Let us consider each method separately.

Social phenomena are continuous. We strive to understand the present and to predict the future by study of the past. The geologist finds in rocks the records of the past and paleontology is the study of fossil evidences of forms of life now extinct. The social scientist has no such direct and objective evidence of past phenomena. He must, consequently, resort to the observations of past events made by contemporary observers of them and recorded in historical documents.

Historians have developed a method of criticism of documentary evidence which should supplant the prevailing credulous acceptance of the written word. It is not possible in this short paper to describe the modern *historical method*[7] of documentary criticism, more than to say that it is a highly developed technique for evaluating in truly scientific fashion the records of observations made in the past by persons now deceased. By using this method, we may distinguish between the mere witness of a past event and the reliable observer of it. The social scientist can thus discriminate between fact and fancy and utilize the records of previous observations in a fashion that will make due allowance for the element of bias.

Field work in the social sciences consists of organized and systematic efforts to observe contemporary social phenomena. We may distinguish at least three variations in technique;[8] first, complete enumeration as of a government census of population; second, sampling, or the study of parts less than the whole, often illustrated by the survey method; and, third, case work investigation which supplies a technique for an intensive and many-sided study of the individual.

It is not necessary to describe the work and organization of census-taking[9] beyond stressing the point that a serious and scientific effort is made to obtain accurate and complete enumeration of some important economic, political and social attributes of our citizens. In view of the fact that thousands of untrained enumerators are used for this purpose, a surprising degree of accuracy and completeness of returns is secured by means of careful pre-planning, a detailed schedule, instruction of enumerators and supervision in the field.

[7] Langlois and Seignobos, "Introduction to the Study of History."

[8] Chapman, *op cit.* chs. 1, 3–8.

[9] Decennial Census of the Commonwealth of Massachusetts, 1915, Part I, pp. 3–32.

The survey method is so familiar that it need not be elaborated in detail. The selection of a random sample less than the whole is often the scientific basis for such field work. In this connection, it is merely enough to call your attention to the fact that mathematical formulae are available to test the probable error of such samples. Beyond this, some interesting experiments have been made to perfect the schedule used by the field worker. The schedule is a mechanical instrument of observation and measurement used in social science to extend and standardize the observational powers of the senses. By use of schedules and score cards, it is sometimes possible to measure in quantitative terms social phenomena that ordinarily are described in purely qualitative terms. There is not time nor space to elaborate this point, but I wish to call your attention to various efforts which have been made to develop score cards for the study of the manner of living, housing conditions, neighborhoods and homes.[10] In so far as objective and quantitative terms of description are used in schedules, ordinary bias may be diminished.

The technique of *case work investigation* has been developed by social workers engaged in philanthropic relief and social welfare activities. It is far too elaborate a technique to describe here, beyond saying that the beginnings of a real scientific technique for the study of the individual in his social relations is found in case work.[11] Case work investigation draws upon the historical method in its critical use of documentary sources of information about persons, it draws upon psychology and the science of law in its principles of interviewing clients and weighing and evaluating evidence. Case work investigation has probably done more than any other single influence to make modern relief-giving scientific and constructive.

It is hardly necessary to emphasize the scientific character of the *statistical method*. To save time, then, I shall assume that my readers are familiar with this method; but there are two illustrations of the use of the statistical method made within recent years in which, it seems to me, there exists great promise for overcoming some of the difficulties which stand in the way of using the experimental method in social science.[12] The first illustration that I have in mind is the use of the formula of partial or multiple correlation. By this device, it has been possible to measure the relative importance of different causative factors in a given situation.

[10] Chapin, *op. cit.*, ch. 7, especially pp. 176–185; and Whittier State School (Calif.) bulletins No. 8—"A guide to the grading of neighborhoods," and No. 9—"A guide to the grading of homes."

[11] Richmond, "Social Diagnosis."

[12] Chapin, "The experimental method and sociology," *Popular Science Monthly*, Vol. 4, Nos. 2 & 3, Feb., Mar. 1917; and "Elements of scientific method in sociology," *Amer. Jour. Sociology*, Vol. 20, No. 3, Nov. 1914.

Ogburn[13] has shown that the correlation of food expenditure per man per day with incomes is $r = +0.391$. When the partial correlation coefficient is computed with the size of the family constant, $r = +0.549$. The second illustration is the now familiar case of the business cycle. The studies of Mitchell,[14] Moore[15] and Persons[16] have shown that there are three superimposed fluctuations in a long time series representing certain kinds of economic phenomena. The indexes of prosperity and depression extending over a term of years show a long term trend or tendency to rise or fall; superimposed upon this is the cyclical swing of prosperity and depression; and superimposed on this cycle are seasonal fluctuations. This is a fairly good illustration of the complexity of social phenomena. By means of certain mathematical formulae, it is possible to measure each one of these types of change separately. These two illustrations suggest that the statistical method helps overcome some of the difficulties which stand in the way of a controlled observation of social phenomena.

Relation of These Methods of Social Research to the So-called Scientific Method

Peirce[17] claimed that science is confronted by three tasks: First, the discovery of laws of natural phenomena, performed by the inductive process; second, the discovery of causes, accomplished by hypothetic inference; and third, the prediction of effects, accomplished by use of deduction. If we accept this definition of the practical tasks of science, then the following chart will help us to see the orientation of methods of social research and scientific induction:

Tasks of science	*Scientific method*	*Methods of social research*
1. Discovery of laws by induction	1. Formulation of working hypothesis	(1) Historical method of critical examin. of documents
2. Discovery of causes by hypothetic inference	2. Collection of facts of observation	(2) Field work observation a–complete enumertion b–sampling c–case work
3. Prediction of effects by deduction	3. Classification of facts of observation	
	4. Generalization from facts of observation	(3) Statistical method of interpretation

[13] "Analysis of the Standards of Living in the District of Columbia," Publ. Amer. Statistical Association, Vol. 16, N. S. No. 126, June 1919.

[14] "Business Cycles," 1915, "Business Cycles and Unemployment," 1923.

[15] "The laws of wages," 1913, "Economic cycles—their law and cause," 1914, "Generating economic cycles," 1923.

[16] Review of Economic Statistics, by the Harvard Committee on Economic Research.

[17] "A Theory of Probable Inference," Johns Hopkins University, *Studies in Logic*, 1883.

If the test of science is its power to predict future events, then the social sciences are deplorably weak on this test. The chief reason for this weakness in prediction is that social sciences are in a theoretical and speculative stage of development because their laws are empirical laws at best, and not scientific laws. It has already been pointed out that scientific induction is the only foundation upon which a generalization can rest, if that generalization is to be used with assurance as a basis of prediction. At the present time social sciences have inadequate facts for induction and students tend to be more interested in speculation than in observation.

But there is another larger aspect of the failure of social science to develop generalizations from which valid predictions can be made, and the failure to supply a practical applied social science.

It seems to be true that a certain general cultural threshold must be passed before certain other cultural advances can come. In applied science, the practical aeroplane could not have been developed until a light unit for motive power had been invented, *e.g.*, the internal combustion engine, and this in turn could not be developed until chemistry and electrodynamics had reached a certain stage. The great newspaper machine presses of to-day are not to any great extent the result of an empirical trial and error process, but are derived from inventions based upon scientific discoveries.

Bernard[18] contends that inventions in the field of the physical sciences, applied to economic and industrial activities, have passed very largely out of an empirical stage and are now in the stage of projected invention. In projected invention a vast number of mathematical or mechanical formulae are prepared and reduced to logical order on paper. These formulae are often visualized by transfer to blue prints; finally, the machine is constructed to correspond to the blue print. In the field of chemistry we find examples of projected inventions made on the basis of antecedent method inventions in chemistry and mathematics. This would be true of such discoveries as TNT, the high explosive, as well as of synthetic rubber. Thus, in modern machine manufacture and in the production of textiles, foodstuffs and many other manufactured articles of commerce, the laboratory sciences of chemistry, physics and their affiliated sciences are in a scientific stage of development of what has been called projected inventions. By contrast, in social relations we fail in statecraft, in political activity, in organization of industrial relations and in the care of dependent, defective and delinquent classes chiefly for the reason that the sciences basic to any scientific treatment of these problems are still in an empirical

[18] "Invention and social progress," *Amer. Jour. of Sociology*, Vol. 29, No. 1, July, 1923, pp. 1–33.

and a speculative stage of discovery and invention. The social studies can not pass from this empirical stage and attain the truly scientific stage until they use the inductive method more generally as a necessary preliminary to deduction and prediction.

Organized Efforts to Study Social Phenomena in a Scientific Manner

In general, it may be said that in our universities that possess strong graduate departments of economics, political science and sociology, real scientific research is being carried on. The historical method, careful field work studies and statistical interpretation are widely used in these university departments.

When it comes to describing the work of typical research agencies outside of our universities, one finds the field of bewildering complexity. I shall, therefore, merely mention a few illustrations of organized efforts to conduct social research in accordance with scientific principles.

In the field of political science there is a large number of privately or publicly supported bureaus of municipal research, institutes of public service, or legislative municipal reference bureaus. In this connection I wish to call your attention to the recent report of the committee on political research of the American Political Science Association.[19] In this report you will find a description of research activities in the field of politics.

At the present time a considerable number of privately endowed bureaus and foundations for economic and industrial research exist. These bureaus vary in organization and in the range of subjects studied. Some are undoubtedly more interested in pure science, while others are more interested in immediate and profitable application of the findings of economic research to pressing commercial and industrial problems. The American Economic Association has a joint committee with the American Statistical Association, advisory to the Federal Census. This committee has done notable work in suggesting to the officials of the Federal Census improvements in the technique of gathering information and of its interpretation. The American Economic Association has also had a committee on terminology, which indicates that there is an active interest in standardizing terms in accordance with better scientific practice.

In the sociological field investigations have been carried on by national foundations such as the Russell Sage Foundation, the Carnegie Corporation, the Commonwealth Fund and others. The

[19] "Progress report of the committee on political research," *Amer. Pol. Sci. Review*, Vol. 17, No. 2, May 1923, pp. 274–312.

American Sociological Society has a standing committee on social research and a standing committee on social abstracts.[20] Among the scientific workers in the applied and practical fields of sociology, there should be mentioned the various committees on terminology of the American Association of Social Workers.

No treatment of this subject would be complete without mentioning the fact that a National Social Science Research Council was organized in the spring of 1923. This council is composed of delegates from the four following social science associations: The American Economic Association, the American Political Science Association, the American Statistical Association and the American Sociological Society. This organization is at present engaged in planning a survey of the entire field of social research in the United States. It is also considering the possibility of organizing a social science abstract service which will make accessible to scholars and research workers in the field of the social sciences the vast amount of periodical literature on social science now almost inaccessible because of its overwhelming volume.

[20] See annual reports of these committees in the Proceedings of the Amer. Sociological Society for 1920, 1921, 1922 and 1923.

THE ASTRONOMY OF SHAKESPEARE

By JOHN CANDEE DEAN

SHAKESPEARE's position in relation to earlier English literature was similar to that of the great Greek sculptors in respect to their earlier art. His writings abound in conceptions of life, wherein he displays exquisite skill in depicting mankind in perfect harmony with nature. While he is said to have possessed but little knowledge of Latin, and less of Greek, he appears to have been well informed in current philosophy and science of the Elizabethan period, so much so that his plays are sometimes said to have been written by the greatest philosopher and scientist of his time, the so-called father of inductive reasoning.

Shakespeare's writings teem with references to astronomy, and it may be of interest to examine into his conceptions of that science. For ages the superstitions of astrology had ruled the people of the world, and in the sixteenth century they had lost little of their power. Although Elizabeth had strong common sense, and was something of an agnostic, she had her astrologer, and sometimes followed his advice in important matters. In 1580 she issued an order of prayer to avert God's wrath, in which she referred to eclipses, comets and even heavy falls of snow as evidence of His great displeasure.

Shakespeare was born 21 years after the death of Copernicus, yet there is nothing in his writings to indicate that he ever heard of the Copernican theory. All his references to astronomy are based on the old geocentric theory. Galileo was born in the same year that Shakespeare was. He invented his telescope and discovered the system of Jupiter's planets when he was 45 years old, yet there are no references to Galileo in Shakespeare's works. However, we must not be astonished at this apparent ignorance; it took 200 years to establish the Copernican theory in the minds of even educated people.

Shakespeare was really quite advanced in the philosophy of his time. He did not believe in astrology, when nearly the whole world did. He disclaims this belief in his Sonnet XIV, where he says:

> Not from the stars do I my judgment pluck;
> And yet methinks I have astronomy,
> But not to tell of good or evil luck,
> Of plagues, of dearths, or seasons' quality.

While he knew astronomy, he did not employ it to predict the weather, luck, or death, etc.

In "King Lear," Edmund rails at astrology.

> When we are sick in fortune, we make guilty of our disasters, the sun, moon and stars; as if we were villains on necessity, fools by heavenly compulsion. Knaves, thieves and treachers by spherical predominance; drunkards and liars by enforced obedience to planetary influence; and all that we are evil in, by a divine thrusting on.

This reads like an expression of Shakespeare's real contempt for this pseudo-science. He depicts Roman superstitions in "Julius Caesar," where Calphurnia warns Caesar of his danger through premonitory signs:

> A lioness hath whelped in the streets,
> And graves have yawned and yielded up their dead.
>
> Horses do neigh, and dying men did groan,
> And ghosts did shriek and squeal about the streets.
>
> When beggars die there are no comets seen,
> The heavens themselves blaze forth the death of princes.

Caesar's reply to this is worthy of him:

> Cowards die many times before their deaths,
> The valiant never taste of death but once.

It is a most singular coincidence that a brilliant comet did appear three months after Julius Caesar's death, when Rome was in a turmoil. The comet was supposed to be Caesar's metamorphosed soul armed with fire and vengeance. In his beautiful painting "The Ides of March," E. J. Poynter, P. R. A., shows Calphurnia pointing out to Caesar the alarming apparitions in the evening sky, in which a comet is shown, but the painter had antedated its appearance by three months.

Just before his death, Caesar had compared his constancy with that of Polaris:

> I am as constant as the northern star
> Of whose true-fix'd and resting quality
> There is no fellow in the firmament.
> The skies are painted with unnumbered sparks,
> They are all fire, and everyone doth shine,
> But there's but one in all doth hold his place.

In "Hamlet," Horatio describes the strange phenomena of the heavens over Caesar's death:

A little ere the mightiest Julius fell,
The graves stood tenantless and the sheeted dead
Did squeak and gibber in the Roman streets,
As stars with trains of fire and dews of blood,
Disasters in the sun, and the moist star,
Upon whose influence Neptune's empire stands
Was sick almost to doomsday with eclipse.

The "moist star" is the moon which causes the tides and was supposed to control the weather by bringing rain. This superstition of the moon's influence on the weather still strongly persists, but carefully recorded observations, covering many years, at Greenwich Observatory prove that there are no relations between the moon's changes and the weather.

In "The Tempest," Miranda asks her father why he has brought on the tempest. Prospero replies:

Now my dear lady, hath mine enemies been
Brought to this shore, and by my prescience
I find my zenith doth depend upon
A most auspicious star; whose influence
If now I court not, but omit, my fortunes
Will ever after droop—Here cease more questions.

We thus see that Prospero's "auspicious star" has been courted to assist in bringing his enemies to his magic island.

In "Romeo and Juliet," Juliet says:

Yon light is not day-light, I know it.
It is some meteor that the sun exhales
To be to thee this night a torch-bearer.

The idea that meteors have come from the sun is not inconsistent with the recent planetesimal hypothesis.

Copernicus published his great work, "The Revolution of the Heavenly Bodies," 21 years before Shakespeare was born. A few men of learning read it, the church rejected it, and it received but little attention until the time of Galileo, who was born the same year that Shakespeare was. The church saw new dangers in the discoveries of Galileo, and used its great powers to overthrow them. Galileo was accused of heresy and atheism, and was imprisoned. He lived to see his works expelled from all the universities of Europe and their publication prohibited.

The latter part of the sixteenth century was a period of great longings for knowledge by the educated class. Christopher Marlowe, poet, dramatist and friend of Shakespeare, in his play of "Tamburlaine," beautifully expresses the higher human aspirations of this period:

Nature that formed us of four elements,
Warring within our breasts for regiment,
Doth teach us all to have aspiring minds;
Our souls, whose faculties can comprehend,
The wondrous architecture of the world,
And measure every wandering planet's course,
Still climbing after knowledge infinite.
And always moving as the restless spheres,
Will us to wear ourselves, and never rest,
Until we reach the ripest fruit of all.

The average man loves superstition, loves and fears the supernatural, and is fascinated by the incomprehensible. Idle fancies are still cherished that the mind and body are affected by the light of the moon, that its rays sometimes produce blindness by shining on the sleeper's eyes, that death occurs at the time of the change of tide, and that insanity is produced by the moon's influence. When Emilia discovers that Desdemona has been murdered, she calls to Othello, "Oh, my good lord, younder's foul murther's done." Othello replies:

It is the very error of the moon;
She comes more near the earth than she was wont,
And makes men mad.

In other words the moon was in perigee, the most dangerous point in its orbit, and under its influence he had committed the murder while temporarily insane.

Astrology taught that eclipses expressed the distress of nature over terrestrial calamities, while comets portended greater woes than all the other celestial signs combined. Luther declared them to be the work of the devil and called them "harlot stars." Even Milton says that the comet "from its horrid hair shakes pestilence and war." Whole nations from the king down to the lowest peasant were frequently plunged into the direst alarm by the appearance of these messengers of misery.

Lord Francis Bacon, lawyer, philosopher and scientist, probably never met Shakespeare. Each was doubtless unconscious of the other's genius. The difference in rank, at that time, was sufficient to prevent their meeting. Bacon evidently never read Shakespeare's poetry, never went to see his plays and did not seek the author. In his "Advancement of Learning," Bacon wrote nobly of the poet's art, but nowhere does he exhibit any knowledge of Shakespeare's plays, which 300 years later were thought by many to be so great that none but Bacon could have written them. Bacon's talents have been overestimated by literary men who had little idea how scientific discoveries are made. He was ignorant

of higher mathematics and thought them useless in scientific investigations. He made many mistakes, the greatest of which was that of rejecting the Copernican system of astronomy, and went to his grave believing that the earth was the center of the whole universe. The illustrious Newton never acknowledged that he was under any obligation to Bacon. Newton knew that nature always works by geometry, and achieved his great discoveries through mathematics. There seems to be little evidence that Bacon could have written the plays of Shakespeare.

Some of us still remember Henry Irving's lovely moonlight scene in Portia's garden at Belmont where Lorenzo and Jessica were awaiting the return of Portia from the trial of the merchant Antonio. One of the most beautiful passages in Shakespeare is presented when Lorenzo, after requesting that the musicians be brought into the open air, says:

> How sweet the moonlight sleeps upon this bank!
> Here will we sit and let the sounds of music
> Creep in our ears; soft stillness, and the night
> Become the touches of sweet harmony.
> Sit, Jessica. Look, how the floor of heaven
> Is thick inlaid with patines of bright gold.
> There is not the smallest orb which thou beholdest,
> But in his motion like an angel sings,
> Still quiring to the young-eyed cherubims:
> Such harmony is in immortal souls;
> But while this muddy vesture of decay
> Doth grossly close it in, we can not hear it.

Here with delicate beauty the Greek theory of the universe is set forth. The idea of a spherical universe was a very natural one. It was believed that the planets and stars were set in a series of concentric spheres, each so perfectly transparent that bodies in the more distant ones were visible through all the intervening ones. Each planet had a separate sphere.

In Italy the stars burn with a piercing brilliancy. The planets are wonderfully radiant. While on Lake Maggiore on clear summer nights, the writer witnessed a brightness of the stars, planets, the galaxy, and of the zodiacal light, unequalled in the Mississippi valley.

Milton in his "Arcades" parallels Shakespeare's lines, but in beauty, sentiment and harmony, it will be seen that he falls below the great master:

In deep of night when drowsiness
Hath lock'd up mortal sense, then listen I
To the celestial Siren's harmony,
That sits upon the nine infolded spheres.
Such sweet compulsion doth in music lie,
To lull the daughter of Necessity
And keep unsteady Nature to her law,
And the low world in measured motion draw
After the heavenly tune which none can hear
Of human mould, with gross unpurged ear.

Dante in his "Paradise" describes the crystal orbs as being rotated by angels.

The virtue and the motion of the sacred orbs,
As mallets by the workman's hand must needs
By blessed moovers be inspired.

While Shakespeare was writing his plays Giordano Bruno visited England, where he resided for a time. He delivered lectures at Oxford University on the astronomy of Copernicus and published his exposition of the Copernican system.

From the second century to the beginning of the fifteenth century, a period of 1,300 years, the theory of astronomy had remained unchanged. The divine music of the revolving spheres could be heard only by angels and immortals. According to Ptolemy, the abode of the blessed was outside of the sphere of the fixed stars. In 1607 the world was thrown into consternation by the appearance of Halley's comet. Kepler, royal astronomer at Prague, and discoverer of the laws of planetary motion, quietly traced its course and found that it came from outside of the moon's orbit. This announcement caused a great outcry because it assailed the dogma of the crystalline spheres. The course of a super-lunar comet would send it crashing through the spheres. Kepler was abused, imprisoned and warned that he must bring his theories into harmony with the scriptures.

In 1607, when Halley's comet appeared, Shakespeare was still occupied as actor, manager and writer of stage plays. This brilliant comet probably caused more consternation than any other within historic times. Shakespeare was, therefore, a witness of the alarm of the world over the appearance of this dire messenger of woe, when the churches filled with terror-stricken multitudes.

The following lines are from "Troilus and Cressida":

The heavens themselves, the planets, and this center,
Observe degree, priority, and place,
Insisture, course, proportion, season, form,
Office, and custom, in all lines of order.

Shakespeare here exhibits a true sense of the orderly invariability of nature's laws, as announced about forty years after his death by the French philosopher Descartes, who was the first to declare nature's laws to be unchangeable. By "this center," the poet, of course, refers to the earth. Here the geocentric hypothesis of Ptolemy reappears.

In "Measure for Measure," there is a single line of the highest poetical quality which brings up a mental picture of the approaching dawn.

"Look, the unfolding star calls up the shepherd." The "unfolding star" is Venus, which appears over the eastern hills at early dawn, and calls the shepherd to release the flock from the fold while the grass is still wet with morning dew.

THE PHYSICAL BASIS OF DISEASE

III. TISSUE DEGENERATION

By THE RESEARCH WORKER
STANFORD UNIVERSITY

"Our Boston acquaintance seems to have taken offense," said the lawyer, as he welcomed the manufacturer and the research worker to his compartment the next morning.

"He said he didn't care to listen to any more heresies," said the manufacturer.

"I fear I was not successful in differentiating between the field of formal biological science and that of religious speculation and belief," replied the research worker. "Formal biology is concerned solely with material facts. Religion deals essentially with facts beyond the reach of material science. I see no reason why the two fields should ever be in conflict. My own religious beliefs or disbeliefs are not based on material facts. They haven't been altered, so far as I can see, by my formal scientific training."

"Aren't all biologists atheists?" asked the lawyer.

"There is as wide diversity of religious belief among biologists as among people of the same grade of intelligence in other walks of life."

2

"As our third group of diseases," continued the research worker, "I have selected diseases due to degenerative changes in important organs or parts. Such degenerations may affect any organ or tissue of the body. One of the best examples of such degenerations is the change in muscles and bones in infantile paralysis. We have seen that the essential or fundamental injury in infantile paralysis is death of certain portions of the gray matter of the spinal cord. As a result of this nerve cell death, certain muscles can no longer be used. Prolonged disuse of these muscles leads to their degeneration and decrease in size. The muscles or portions of muscles affected are eventually reduced to flabby strands but a fraction of their original size. Microscopic examination shows the contractile fibers in these muscles markedly shrunken, atypical in structure, and decreased in number, the main body of the muscle being composed of inert scar tissue.

"One of the distressing effects of this muscular degeneration is the production of unsightly deformities of the bones. Such

degenerations usually destroy the mechanical balance between antagonistic muscle groups, so that the bones are constantly being drawn toward an abnormal position. The bones are gradually distorted by this new pressure relationship."

"I shouldn't think changes in pressure would alter the shape of bones," said the manufacturer.

"The bones are not inert structures. Look at any bone with a magnifying glass and you will see innumerable small openings or pores. These are passages for minute blood vessels and accompanying structures. At certain points the solid bone is being constantly eroded and absorbed by these structures. The bone is being constantly strengthened or built up at other points. The entire skeleton is virtually torn down and rebuilt by this method several times during average adult life. This tearing down and rebuilding of bone is governed largely by pressure relationships. Altered pressure relationships cause the bones to be rebuilt in atypical shapes."

3

"Degenerations of the same type may take place in internal muscular structures of the body. They are fairly common, for example, in the heart. In elderly individuals or in young individuals as the result of the action of toxic or infectious agents, the walls of the heart become flabby and may be reduced to but a fraction of their normal thickness. In certain cases, little or no change in the thickness of the heart walls takes place, but on microscopic examination the muscle fibers are found shrunken, atypical in structure and reduced in number. The walls of such hearts are composed largely of inert scar tissue. The available strength of a degenerate heart is less than normal. While a normal heart rarely uses more than 10 per cent. of its available strength to maintain normal circulation, the degenerate heart may require half or even its entire available strength. Its reserve capacity or factor of safety is very small."

"Degenerate hearts are not only weaker than normal, but may show marked changes in the nature of their contractions. With severer degenerations the contractions are often delayed or sluggish, reducing the heart rate. With milder degenerations, the heart muscle may be unusually irritable, contractions occurring at much greater frequency than normal. Irregularities in the rate and in the strength of the contractions often occur. Coordination of different portions of the heart muscle may be interfered with. Different chambers of the heart, for example, may beat at different rates. One chamber of the heart may contract at such a time

as to prevent its normal filling with blood from the preceding chamber. Such a heart uses up a large part of its available strength in useless work. In extreme cases, complete incoordination of various portions of the heart muscle takes place. The muscle shows irregular independent twitchings, jerkings and worm-like movements of its different parts. Orderly contractions are no longer possible."

"I should think that would kill a person immediately," said the manufacturer.

"That depends upon the portion of the heart affected. The auricles, for example, may be completely paralyzed by this method, and enough blood be forced or sucked through them to maintain life."

"Is that what is known as palpitation of the heart?" asked the lawyer.

"Palpitation of the heart is a term usually applied to any abnormal consciousness of heart action. This may be due to abnormal heart action. It is often, however, a purely psychological phenomenon due to heightened consciousness of heart action. I should prefer to postpone discussion of this topic till we take up diseases due to psychical factors.

"Muscular degenerations are also found in the blood vessels. We have seen that the artery walls are composed of muscle fibers and supporting tissues. The muscle fibers usually decrease in size and in number in advanced life. They may become degenerate in early life as a result of toxic and infectious agents. The artery walls may be virtually reduced to inert scar tissue. Degenerate arteries are weaker than normal, and show an increased tendency to rupture. They are also relatively inelastic. They tend to remain expanded to their maximum diameter, even with low blood pressure. One of the effects of this loss of elasticity is to increase the amount of work necessary to maintain normal circulation. Greater force is required to force blood through the inelastic arteries, than through the normal rubber-like blood vessels."

4

"Serious circulatory disturbances may also result from degenerations in the blood itself. The blood, as you know, is a nearly colorless fluid in which are suspended numerous minute cells, the red blood corpuscles. These corpuscles are of uniform size, uniform shape and of uniform color. Blood degenerations may show themselves by a reduction of the number of these red blood corpuscles, by irregularities in their size, irregularities in shape or irregu-

larities in color. The blood, for example, may contain but half of the normal number of red blood corpuscles per unit volume. Many of these corpuscles may be deformed and but half their normal size. They may contain little or no red coloring matter. The red blood corpuscles, as you know, are the oxygen-carrying mechanisms of the blood. They take up oxygen in the lungs, and give off oxygen where needed in the internal organs."

"They're intelligent," said the manufacturer. "Loading up with oxygen in the lungs, and dumping oxygen where needed in the body. Clever work."

"So far as we know, no intelligence enters into this process. The action of the corpuscles is due solely to the chemical properties of the red coloring matter they contain. This coloring matter outside the body absorbs oxygen from the air, and gives off oxygen if the amount of oxygen in the surrounding medium is sufficiently reduced. Many other chemical substances will act in the same way."

"Our Boston acquaintance would call this atheism," said the lawyer.

"There is no suggestion of atheism in it. Biologists have simply explained one of the mechanisms by means of which the mysterious life force operates. They offer no explanation as to the nature of this life force.

"Blood degenerations usually reduce the oxygen-carrying capacity of the blood. This is due to a reduction in the amount of red coloring matter. There is normally a very generous factor of safety in oxygen-carrying capacity. Blood usually carries three times the amount of oxygen needed by internal organs. The red coloring matter of the blood may be reduced to a quarter of the normal amount, and still be able to supply all ordinary tissue needs. One of the ways in which the blood is assisted in doing this is by an increase in the rate of blood flow. The blood is thus used more frequently than normal to transport oxygen to the tissues. This increased blood flow of course throws an additional burden on the heart."

5

"Equally striking degenerations take place in the respiratory system. A good example is the collapse of a portion of the lungs following occlusion of a bronchus. If a bronchus is plugged by a foreign object or by exudate, or is closed by swelling of the bronchial walls, or by outside pressure, the portion of the lungs supplied by this bronchus is cut off from its external air supply. The air contained in this portion of the lungs is gradually absorbed.

This portion is eventually reduced to a shriveled, airless mass of solid tissue. Blood passing through this portion of the lungs is of course no longer supplied with oxygen.

"A second example of respiratory degeneration is cavity formation from bronchial dilatation. Degenerative changes in the bronchial walls may so weaken these walls as to lead to their gradual inflation. In extreme cases, immense cavities may be formed by this method. A whole lobe of the lungs may be changed to an open cavity, surrounded by collapsed or semi-collapsed lung tissue. Blood passing through this portion of the lungs is incompletely aerated.

"Degenerations may also take place in the air sacs. The walls of these air sacs become weaker than normal, and lose their elasticity. Neighboring air sacs may rupture into each other, forming minute cavities. The individual air sacs are often permanently dilated to many times their normal diameter. A lung that is covered with hundreds of bladder-like cavities is not unusual. The ventilation of these cavities is usually defective. The blood is inadequately aerated. On account of the generous reserve oxygen-capacity of the blood, incomplete aeration is usually not a serious matter. It reduces one of the important factors of safety, however, in all organs and tissues."

"I don't see what a physician can do to cure such cases," said the manufacturer.

"I should prefer to postpone discussion of treatment till we have completed our review of the different types of disease. In some cases almost miraculous cures can be effected. In many cases, readjustments of the mode of life may be made that will allow the person to live comfortably with his reduced factors of safety."

6

"Very striking degenerations are found in the digestive tract. The stomach lining, for example, may be shriveled to but a fraction of its normal thickness. This lining, as you know, contains the glands that secrete gastric juice. With such degenerations, the amount of gastric juice is usually reduced. Its chemical nature is often altered. The digestive processes are usually atypical. Putrefaction of food may take place.

"Equally striking degenerations may take place in the muscle fibers of the stomach walls. These may be markedly shrunken, atypical in structure, or decreased in number. In extreme cases the walls may be reduced to inert scar tissue. Muscular degenerations reduce the power of the stomach to cause proper movement of food. Stagnation and putrefaction of food may result.

"Probably the most striking examples of degeneration in the digestive system take place in the liver. The liver, as you know, is not only a digestive organ, but is one of the main blood-purifying organs of the body. Blood circulating through the walls of the intestines, for example, is purified by the liver before being returned to the general circulation. Bacteria and toxic substances are absorbed or filtered out.

"Microscopically the liver is seen to be composed of special liver cells, held in place by supporting tissues, and richly supplied with blood vessels. Marked degenerations may be produced in the liver cells as a result of the action of toxic or infectious agents. The cells are shrunken, atypical in structure, and diminished in number. The whole liver may thus be reduced to a fraction of its normal size. Often, however, the size of the liver is not reduced, the shrunken liver cells being replaced by scar tissue. The liver may even be increased by this scar tissue growth to two or three times its normal size.

"Degenerations usually reduce the detoxicating powers of the liver. The liver, however, has a very generous reserve capacity, so that it does not become incompetent for the normal needs of the body till nearly two thirds of the liver cells are thrown out of function. Excessive amounts of scar tissue in the liver, however, may produce serious mechanical effects, even though the liver is otherwise competent. The scar tissue usually increases the resistance to blood flow through the liver. Blood is mechanically dammed back into the stomach and intestines, causing marked engorgement of these organs. With prolonged engorgement there is often a constant outward leakage of the blood plasm into the abdominal cavity. Many quarts of fluid may thus accumulate."

"An incurable condition," said the manufacturer.

"Not necessarily. Small veins passing upwards along the esophagus, for example, may gradually enlarge so as to effectively drain off the excessive blood from the stomach and intestines.

"Another striking degenerative process in the liver is the formation of gelatinous deposits. In certain chronic diseases, chemical alterations are produced in the blood and body fluids, sufficient to cause gelatinous material to be precipitated or deposited in tissue spaces. These gelatinous deposits may be so marked in the liver, for example, as to surround and kill the liver cells. Large portions of the liver may be thus replaced by firm gelatinous masses, resembling soft rubber. This gelatinous material has some of the properties of stiff starch paste."

7

"Degenerations are equally common in the nervous system. This, of course, is a normal process in advanced age. In younger individuals nerve cell degenerations may be produced as a result of the local action of toxic agents or of disease-producing microorganisms. Degenerations follow local circulatory disturbances. In experimental animals, nerve cell degenerations may be produced by prolonged loss of sleep, excessive muscular activity or emotional excitement. In certain individuals, nerve cell degenerations take place without assignable external cause. Statistics show that they are usually the result of defective hereditary endowment.

"Degeneration of the nerve cells may be general throughout the nervous system, or it may be confined to certain areas or structures of the brain or spinal cord. Microscopically the nerve cells may be shrunken, distorted, may contain cavities or vacuoles or may be filled with granular deposits. The nerve fibers connecting the cells may be shrunken, fractured or even absent. The space originally occupied by the nerve cells may be filled with fluid or occupied by scar tissue.

"The effects of degenerations upon the activity of the nerve cells depend upon the type and degree of degeneration. Pronounced degeneration usually reduces the activity of the nerve cells. Severely degenerated portions of the brain or spinal cord respond only to unusually strong stimuli. In extreme cases the reacting power is completely lost. Milder degenerations may actually increase nerve cell activity. Such cells respond with explosive violence to stimuli that would not affect a normal cell. They may even be thrown into explosive activity with no demonstrable external cause.

"The resulting symptoms depend upon the number and location of the nerve cells affected. With severer degenerations the symptoms approach those of death of nerve cells, which we have already considered. There may be partial loss of the power to receive or recognize sensations, reduction in the power to initiate or coordinate muscular movements, and reduced power to inhibit instinctive actions.

"With less severe degeneration, there may be heightened nerve activity. A gentle touch on the skin, for example, may be felt as unbearable pain; the ticking of a watch may be heard as pistol shots; ordinary desire for food may be felt as wolf-like hunger. Sensations may even arise with no demonstrable external cause. The ticklings, tinglings, sense of pressure and shooting pains, which are often experienced in early syphilitic degenerations of the spinal cord, are good examples. Visual hallucinations may

result, false auditory sensations, delusions of muscular movements, fictitious feelings of disturbed equilibrium.

"Milder degeneration may also produce marked changes in muscular activity. In the early nerve cell degenerations of tetanus, for example, a gentle touch on the skin may throw all muscles of the body into such prolonged explosive contractions that death may result. Uncontrollable twitchings, jerkings or prolonged muscular contractions may take place, with no demonstrable external cause. Uncontrollable complex instinctive actions.

"The usual general effects of nerve cell degenerations are reduced mental capacity, and altered personality and character. Marked degenerations give the various types of feeble-mindedness, dementia and insanity."

"It is a wise provision of law not to hold these persons legally responsible," said the lawyer.

"Individuals with sufficiently marked nerve cell degenerations to cause them to be classed as feeble-minded or insane are not held legally or morally responsible. How about individuals with milder degenerations? Should they be held responsible?"

"The line must be drawn somewhere," said the lawyer.

"Might not our charitable point of view be broadened to include these individuals?"

"The nervous system has low factors of safety when compared with other organs. There is far less reserve capacity than in the heart and liver, for example. Powers of regeneration are almost absent. Recovery is possible with the milder types of degeneration. Severe degenerations once produced are usually permanent."

"How about prevention?" asked the lawyer.

"One of the main causes of nerve cell degeneration is venereal disease. Visit almost any of our state institutions for the feeble-minded or insane. You will find a quarter to a half of the inmates, and sometimes more than a half, with nerve cell degenerations due to acquired or congenital syphilis. As a purely business proposition, it would pay any state to spend a million dollars a year to stamp out this disease.

"A serious difficulty in prevention arises from the large hereditary factors in nerve cell degenerations, individuals who develop senile changes in the nervous system either in childhood or in early adult life, without assignable or adequate outside cause. There are probably at least two million individuals in the United States at present whose descendants, even under the best hygienic and industrial conditions, will almost invariably develop nerve cell degenerations."

A JOURNEY IN SIBERIA

By Professor T. D. A. COCKERELL

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It all came about through the discovery, by Mr. A. Kuznetzoff, working for the Vladivostok Museum, of two remarkable fossil insects on the Kudia River. These fossils, together with plant remains from the same locality, were referred to Dr. A. N. Kryshtofovich for investigation. He published an account of the plants[1] and sent the insects to the U. S. National Museum, whence they were transmitted to me. They proved to represent new genera of Panorpidae and Delphacidae, members of a hitherto unknown Tertiary fauna. Mrs. Cockerell at once proposed an expedition to Siberia to investigate the locality, but I did not believe such a thing possible. A friend in Washington advised us that the "Reds" were in control and it would be out of the question to visit the country. In the meantime, however, Mrs. Cockerell had written to Dr. Kryshtofovich, who at once replied in enthusiastic terms. At the request of the Geological Committee, the "Supreme Administrative organ of the Far East of Russia" gave permission for us to enter the country for the purpose stated. We secured a passport from Washington, but as our government does not recognize the Russian republic, it was impossible to get a visa in the United States. The same difficulty existed in Japan, so that we were obliged to proceed without an official visa, though we carried a letter from Mr. Boris E. Skvirsky, the unofficial representative of Russia in Washington. Optimistically assuming that everything would be all right, we crossed Japan to the port of Tsuruga, where the "Hozan Maru," with steam up, was waiting to carry us across the Japan Sea. Here we were unexpectedly halted by the local steamship office, the officials making various excuses for refusing to allow us to proceed. Much later we were told that they suspected that we were Russians trying to get into the country to create trouble, and feared the penalties which might be imposed by the "Red" government. The result was that we spent an extremely interesting and profitable week in Tsuruga, so that the delay eventually caused us no regret. Thanks to the activities of our friends in Yokohoma and Vladivostok, by the end of the week the Osaka Shosen Kaisha people were in a very amiable frame of mind, and gave us the best cabin on the boat. We had

[1] Records of the Geological Committee of the Russian Far East No. 15 (1921).

good weather across the Japan Sea, but when we approached Vladivostok we ran into dense fog and were obliged to wait for about twenty-four hours before proceeding into the narrow and tortuous channel leading to the city. We were in shallow water, and the captain and crew interested themselves in fishing with lines, catching great numbers of flounders, apparently of the species *Paralichthys olivaceus* (Schlegel), originally described from Nagasaki. Dragonflies flew about the ship—our first sight of the insect-fauna of Siberia.

When we eventually arrived at Vladivostok, Dr. Kryshtofovich met us at the wharf, and we had no difficulty whatever with the officials, although next day the customs officials considered it necessary to make a catalogue of the entire contents of our two boxes. A little later we called on the Governor of the Maritime Province, who made a very courteous speech welcoming us, and provided us with a "mandate," signed with communistic red ink, requiring every one to give us prompt service and aid us in our scientific work. This document, representing the highest authority in that part of the country, smoothed our path on numerous occasions. This is not the place to discuss the Russian political organization or to enumerate the merits and faults of the Soviet government, but it will not be amiss to allude to those conditions which directly affect science and education. It is the policy of the government to extend and develop the educational system until every Russian has at least a common school education. This is a gigantic task, requiring funds and teachers not yet in sight, but it is the necessary step in developing any kind of functional democracy. It has often happened that educational programs have existed only on paper, lacking the popular interest and support to give them reality. We had ocular evidence that in Vladivostok, at least, the public was really aroused. When we arrived, they were having a school exhibit of the type commonly seen in America, except that one noticed the added feature of red flags, busts of noted communists and posters representing communistic propaganda. We reached the building about twenty minutes before the doors opened, and, although it was by no means the first day of the exhibit, the sidewalk and street were crowded with people, as if the place were some popular theater or other place of entertainment. Once inside, we found it necessary to almost push our way through the crowds. At certain points, copy-books were provided, and the visitors were invited to express their opinion of what they saw. The superintendent of schools in Vladivostok, we were informed, was an enthusiastic disciple of Professor John Dewey.

There were, of course, occasions for criticism. Some vigorously objected to communistic propaganda in the schools, but to the

"Reds" this has exactly the same significance as "Americanization" in our schools. It represents an effort to make a United Russia, on lines which the authorities consider necessary and desirable. It can not be said, however, that the "Reds" have it all their own way; the strict communists are in the minority, and are criticized without reserve by the rest of the population. Nevertheless, the general opinion is, I think even in communistic circles, that evolution and adaptation constitute the program for the future, and many able men who do not profess to be communists are glad to serve under the present administration, helping to build up a greater and better Russia. Thus we found technical experts, not at all identified with revolutionary activities, carrying on their work in public offices and receiving relatively high salaries. Such were Davidoff of the Hydrographical Institute, Solovieff and Kraloff of the Natural History Museum, Vladimirsky of the Meteorological Bureau, and our friend Kryshtofovich of the Geological Committee. Davidoff had served continuously since the days of the czar, and I saw in his office the proof-sheets of the new coast "pilot," which will total about 1500 pages, as against the 150 pages of the edition of 1907. This work is of the highest value, as it minutely describes and illustrates the features of the very rocky and dangerous Siberian coast, maps of which had been quite unreliable. Unfortunately, the work of surveying has been interrupted, because the "Whites," when forced to leave Siberia in 1922, carried off the only surveying vessel. I also saw in the hydrographical office large collections of marine animals, which will be transmitted to Russian specialists for study. At the meteorological office I saw an instrument, made in 1921 at Vladivostok under Vladimirsky's direction, which automatically registers the direction and strength of the wind every minute of the day. The Natural History Museum is an excellent institution, containing a very good exhibit of the native products of the Maritime Province and Amur country and a large library. It does its work on a minimum of income, and could hardly continue successfully were it not for the rent it derives from a moving-picture theatre next door. In the collection of stuffed animals, we saw the famous Ussuri tiger represented only by a cub; "the Museum is at present too poor to obtain a full-grown animal." There is a named collection of the Lepidoptera of the district, but other insects are lacking, having been sent away to European Russia, where they can be studied. Officially, the museum is under the auspices of the Geographical Society of Russia, but practically it is an independent institution.

The Commercial School, under M. Lutzenko, is a remarkable institution, with a wider scope than the name would suggest. The

library contains 25,000 books, including many valuable scientific works, such as Komarov's "Flora Manshuriae." The department of biology has a good collection, many of the specimens obtained by pupils. A picture of Darwin hangs on the wall. When the Communists came in, there was some question of distributing the materials in the Commercial School, on the ground that other centers were entitled to the same advantages, or all should share whatever was available. It was, however, clearly desirable to maintain the equipment intact, and an appeal to Moscow resulted in an order to leave the school undisturbed. In two important matters reforms were instituted by the communists; girls were admitted to the school, and summer classes for adults were instituted. These changes were of course in line with the declared policy of the government, and with a progressive attitude toward education. There are many women teachers in the school, and we were told that in the classes women, as with us, usually stood higher than the men. Considerable attention is given to music and drama; there is a "Little Theatre," and in one of the rooms we found the students' band learning to play the "International." All the windows have black blinds, so that the cinema can be used by day. The youngest pupils in the Commercial School are 14 years of age.

There is no doubt about the genuineness of the desire for education, and there is no domination by athletic interests such as we have in America. Our interpreter, Mr. A. I. Lavrushin, had been educated in the Commercial School, and I trust he will forgive me for referring to the scope of his knowledge as illustrating the thoroughness and breadth of the course. He had not only learned to speak English, but had acquired a remarkable familiarity with English literature. He knew the principles of physics, chemistry and biology, and could go out in the forest and call the trees by their scientific names. He had been on biological excursions, and in general had advanced to a degree which we should consider quite unusual in the product of a secondary school.

While referring to educational institutions, we should not omit the Y. M. C. A., conducted by an American, Mr. B. Lewis, assisted by Mr. Ivan M. Yaroslavtzeff, a Russian who graduated from the University of Chicago. Mr. Lewis told us that when the "Reds" were coming, the Y. M. C. A. had decided that it could do nothing but leave, but at the last moment it was thought best to remain and see what happened. The Communists appointed a committee of investigation, and after a considerable time reported favorably. They required, however, that the society should admit members regardless of religious affiliations, and the official name was changed to Society Mayak, the Lighthouse Society. In the large hall is a paint-

ing showing a lighthouse sending its rays into the darkness of the night, and a family group pointing to it as a haven of refuge. Actually, the operations of the society are exactly what they were before, and it is doing a great deal of work, of a kind much needed in Siberia. It seems to me that the time is ripe for the establishment of a Y. W. C. A., under whatever designation the government would permit.

When we reached Vladivostok, we found a very interesting exhibition of the products of the Marine Province, which was a little later transmitted to Moscow, to be included in the great exposition of the resources of all Russia. This exhibit had been prepared with the aid of a very substantial grant from the central government in Moscow, and was remarkably comprehensive in its scope. There were hundreds of bags of agricultural seeds from all over the province, and when I asked whether it would be possible to get samples of these for the U. S. Department of Agriculture, I was given a complete set, with no other charge than that for putting the seeds up in envelopes and labelling them. Our department has sent a collection of the seeds of cereals in return. I saw also a very fine collection of Lepidoptera, furnished by Dr. Arnold Moltrecht, of Vladivostok, one of the most learned and enthusiastic lepidopterists I have ever met. Dr. Moltrecht, when I was leaving, gave me a most valuable series of Siberian moths and butterflies for the U. S. National Museum, and I am indebted to him for the names of Lepidoptera which we collected, mentioned in this paper. At the cinema theatre we saw another part of the exhibit, moving pictures showing the activities of the province in great detail. It was not necessary, however, to go to the theatre to see "movies." The government had a "movie" show on the main street, the lantern being on one side of the street and the pictures projected on the other. Any evening one could see a crowd gathered, blocking the sidewalk. Once as we went by, we stopped to see what was offered, and it proved to be a reel of the wonders of California, the ostrich farms, artesian wells, and so forth. Later came some propaganda pictures, but then the crowd began to move away.

The first day in Vladivostok, I went out in search of insects, and got a number of things amongst the grass and weeds at the side of a road near to the hotel. The vicinity of the city is, however, very barren, and for profitable collecting it is necessary to go several miles. As I collected, both children and adults would occasionally stop and show a friendly interest, or even lend assistance; but in no case was I pestered for small coin, as I nearly always was in Madeira. Entomology was by no means an unknown pursuit, and during my stay in the country I came across several amateur collectors.

Our first excursion, under the direction of our guide and interpreter, Mr. Lavrushin, was to Okeanskaja, a sort of suburb about an hour's train journey distant, on the Gulf of Amur. It is not on the open ocean, as the name might suggest, but on a secluded and shallow bay, where the water is calm and warm, and the people come in great numbers during the summer to bathe. There is no town, properly speaking, but only a great number of small houses or cottages among the trees, often with very beautiful gardens. These summer cottages, known as datchas, are delightful places to spend the hot summer months, and the fare on the train, for those who have to work daily in the city, is very small. We were surprised, however, to hear a friend state that she and her little daughter wished to go to their datcha, but did not know whether they could, as it was necessary to get a medical certificate. I supposed of course that the certificate would show the absence of infectious diseases, but this was an entire misconception. The Communists had looked with displeasure on these evidences of bourgeois luxury, but concluded that it was quite legitimate for people to live at the seaside if they were out of health and needed recuperation. So far as we could judge, there was little difficulty in getting the required certificates, and the cure generally seemed to be extraordinarily rapid. But I am not the one to scoff, for it actually happened, later on, that a beatific day at Mme. Polevoi's was the turning point in a bad attack of bronchitis which I had developed in the hills.

Almost the first thing we noticed, on getting off the train at Okeanskaja, was an abundance of the familiar *Rosa rugosa* of our gardens. Here it is a wild plant, and it was very interesting to see that it was confined to the immediate coast, its thick leaves being an adaptation to maritime conditions, though retained when it is artificially grown inland. Maack, who explored the Ussuri country long ago, and collected the flora extensively, evidently did not visit the coast, for he did not get *Rosa rugosa* at all, but only species then referred to *R. cinnamomea* and *R. acicularis,* very similar to our wild roses of the Rocky Mountains. I looked for parasitic fungi on the *R. rugosa* at Okeanskaja, but found only a very sparing infestation, which Dr. Arthur tells me is *Phragmidium rosae-rugosae* Kasai, so far as it is possible to determine from the aecial stage alone. Another plant we soon saw, not previously familiar, was *Actinidia kolomikta* of Maximowicz, very remarkable for the variegation of the leaves, with large pallid, strongly pinkish areas, looking as if diseased, but perfectly natural. This would be an interesting plant for genetic studies similar to those recently carried on by Professor Bateson. The variegation, at least in the specimens I preserved, is confined to the upper side of the leaves.

The wild flowers at Okeanskaja are abundant and beautiful, and are not spoiled by the holiday-makers, although every Sunday the trains bring as many people as they can carry. This restraint is evidently not due to lack of appreciation of flowers for home decoration, as all summer long the flower-vendors abound in the streets of Vladivostok, and seem to have a flourishing trade. Going a little way into the woods, we presently found the fire-flower, *Lychnis fulgens*, the flowers large and of the most brilliant scarlet imaginable. The day was unfortunately wet, so we did not get a single bee. The wet weather was favorable for snails, and turning over some logs, I soon came across the fine species *Eulota maackii* and *E. middendorffii* of Gerstfeldt, originally described in Maack's great work on his travels in the Ussuri country. I noticed that these snails entirely lacked the dark dorsal band on the animal, which is so conspicuous in the common Japanese species assigned to *Eulota*. After getting home, I dissected both Siberian and Japanese species, and have no doubt that the Japanese ones should be placed in a distinct genus, for which Pilsbry's name *Euhadra* is available. While we were turning over logs, Lavrushin suddenly called ont that he had found an animal new to him. It was a salamander, *Salamandrella keyserlingii* of Dybowski; my determination was later confirmed by Dr. Stejneger. This little animal is confined to Eastern Siberia, but it goes north to southern Kamchatka, and inland to Lake Baikal.

The deposit of fossil insects was on the coast, about 400 miles northeast of Vladivostok, in N. Lat. 46°. There are no roads up the coast and the topography of the country makes them impossible without extensive engineering operations. The only way to make the journey is in one of the small steamers which go up as far as Sachalin Island or Nicolaievsk during the summer, stopping at all the coast villages on the way. We arranged to go on the "Aleut," but had to wait some time before she had all her cargo assembled and was ready to go. A special permit was necessary for this journey, and in filling out our papers we were asked for our "Russian" names. Fortunately, through the advice of a friend, we were prepared, and I wrote down Fedor Ivanovitch, while my wife signed Marta Josefovna. These familiar names, composed of one's given name and that of one's father, are used in ordinary intercourse, and a woman consequently keeps her original name, no matter whether she is married. We finally got away late on the evening of July 11, sitting up late to watch the receding lights of Vladivostok, as we steamed out of the bay. The next morning we arrived at Preobrageniya Bay, a small coast settlement. We had only a very

short time, but were able to note the coast flora,[2] *Lychnis fulgens*, *Rosa rugosa*, *Thermopsis fabacea*, *Bistorta*, a small blue *Iris*, apparently *I. sanguinea*, and especially the magnificent *Trollius ledebourii*, the orange flowers with long strap-shaped erect petals and large circular sepals. I pinned 21 insects from this locality, including *Argynnis aglaia* L., the Dark Green Fritillary of English collectors, a butterfly which extends from one end of the Palearctic Region to the other. A second stop on July 12 was at Valentine Bay, where I noted a luxuriance of flowers, *Geranium eriostemon* and what I supposed to be *G. sibiricum*, *Thermopsis*, *Corydalis*, with large yellow flowers, *Spiraea*, *Valeriana*, *Lamium* near *L. album*, but with delicately pink flowers, *Astragalus*, *Chelidonium*, *Polemonium*, *Viburnum*, *Philadelphus* and an orange *Hemerocallis*. There were also oaks, with galls upon them. The time allowed was so short that I pinned only seven insects. *Geranium eriostemon* is a very fine purple-flowered species.

Between Valentine Bay and the next stop (Low Lighthouse), Lavrushin found a handsome moth on the vessel; it was later determined by Dr. Moltrecht as *Odonestis pruni* L., which extends from Eastern Asia to Central Europe, but is absent from England.

On July 13 the "Aleut" put in at Low Lighthouse, where we observed an ornamental *Thalictrum*, with white flowers, *Mertensia maritima* and *Lathyrus maritimus* on the shore, the usual *Rosa rugosa*, etc. I obtained nine insects and a spider. The *Mertensia* and *Lathyrus* are also found on the North American coast.

Later in the same day we arrived at Olga Bay, a beautiful secluded harbor, where we had some hours, permitting an excursion into the woods. Here for the first time we saw peonies growing wild, the flowers white flushed with pink. We had earlier seen them offered for sale in the streets of Vladivostok. The species appeared to be *Paeonia albiflora* Pallas, judging by the general characters and number of petals. Later, when we got to Amagu, we saw Japanese sailors with large bunches of these peonies, carrying them to their ship.

At Olga, Lavrushin found a remarkable bright red polyporid fungus, quite new to me. Through Dr. Britton it was later de-

[2] Before going to Siberia, I copied out short descriptions of many of the recorded plants belonging to the more interesting genera, and these notes, in a small book which I kept in my pocket, enabled me to determine a good many species in the field. In Vladivostok I had the advice of Mme. Kryshtofovich, a very keen botanist, and she kindly supplied me with a long list of the typical plants of different stations in eastern Siberia. Finally, Mr. J. K. Shishkin placed in my hands a named collection of the plants of the Maritime Province; this is now in the New York Botanical Garden. I may also add that I made many notes from Regel's "Ussuri Flora" in Maack's volumes, in the library of the Vladivostok Museum.

termined as *Pycnoporus cinnabarinus,* originally described in 1776 from Carinthia. It is of circumpolar distribution; a second species of the genus occurs in all tropical regions. A satyrid butterfly taken at Olga proved to be *Parage achinoides* of Butler, a far eastern race or variety of the European *P. achine.* This is one of the numerous cases in which the Lepidoptera of this region are appreciably different from their European relatives, yet so close as to be considered races of them. Because the European types were first described, one gets the impression that the Siberian forms have varied from them, but it is of course possible in any case that the far eastern race is the stem or original form of the species, or that both are derived from an ancestor now extinct. We also took the little moth *Miltochrista miniata,* with a beautiful red margin to the wings; a species extending from Europe to Japan.

By the time we got to Tutihe, on July 14, there was a good deal of sea running, and I was in poor form. Mrs. Cockerell and Lavrushin went on shore, and brought back a few insects and a bunch of flowers, including *Petasites, Hieracium, Polemonium, Silene, Iris, Trollius, Geranium* and *Lychnis fulgens.* All these genera are common to North America, but the species are different. The sea got so bad after this that I was totally incapacitated, and felt very much discouraged when it was reported that the captain might pass Amagu Bay altogether, the landing facilities there being poor, and the shore exposed. However, when we finally arrived on July 16, they put us off in a lighter, and at last we stood on the shore which had seemed so distant and difficult of access. The greater part of the population of the small village was there, to see who had arrived and to hear the news. They have no other means of contact with the outside world; no telegraph or wireless. During the long winter months, when the coast is icebound, they are quite isolated. The people at Amagu belong to a sect called the "Old Believers," which separated from the orthodox Russian Church long ago, and went into the wilderness, like the Mormons, to seek security and peace. We were told that they had never had a school, though there had been a little private instruction. The government now expects to establish schools throughout the region, and even in this remote spot we saw the government propaganda in the form of small posters, one of which read: "Without cooperation, not even a plow; with cooperation, a *tractor.*" The district is a rich one agriculturally and quite capable of supporting its population. There was a Japanese vessel in the offing, as the Japanese have a "concession" at Amagu for the cutting of timber. This fact led to an incident which illustrates the almost instinctive nature of Japanese politeness. On our way to the village, we had to cross a small creek on a log. Mrs. Cockerell was half way across, when she seemed to

stumble. A well-dressed Japanese was just in front and before she could slip he was in the middle of the stream, holding out his hand. Would a member of any other nation have shown such prompt and self-sacrificing courtesy? Even Sir Walter Raleigh, in the famous story, undoubtedly saw Queen Elizabeth coming, and had time to consider what he would do with his coat. We spent the night at the house of Mr. Shareipoff, the head man of the village, a tall handsome man, with a large family. The next day we set off on foot for the fossil beds, Shareipoff following with a wagon containing our belongings. Our way lay through cultivated fields at first, then into the forest country for about four miles. Beyond, in the distance, we saw the great Sichota Alin range, the peaks unexplored by the naturalist, but as inaccessible to us as the mountains on the moon. To enter that country we should need a large party, to cut trails and give security from bandits, and the undertaking would require more time and money than we had to spare. Nothing could be more charming than the country we had reached, so far as the eye was concerned; but we soon realized its principal drawback in the shape of innumerable mosquitoes and horse-flies. Nowhere else had we seen them so abundant and so persistent. We had veils, and a large Japanese mosquito net to sleep under, but in spite of this we were badly bitten. At sea, Mrs. Cockerell is immune from seasickness, while I suffer miseries; but on land, I am not seriously affected by insect bites, while she is extremely susceptible, whether in Colorado or Siberia. Thus our stay on the Kudia River was not without its disadvantages, in spite of the beautiful country and good collecting. We went first to look at the fossil bed, which occupies a very limited area on one side of a bend of the Kudia River, hardly a hundred yards of exposure.. To make matters worse, since the time of Kuznetzoff's visit, the clay bank above had fallen down, so that the fossil-bearing rocks were covered by talus, which it was necessary to remove. The whole slope was at a maximum angle, and began to slide at the least disturbance, while fresh lumps of the clay rock frequently dropped from the cliff above. In spite of these difficulties, we at once began to find specimens of the commoner fossil plants of the locality, such as *Sequoia langsdorfii, Ginkgo adiantoides, Alnus corylina (A. corylifolia),* etc. A piece of fossil bark, with lenticels, was, I thought, from the *Alnus*. There were at least three species of *Pinus* (pine tree), with two, three and four needles to the bundle, respectively. The present flora of the region includes no 3-needle pines, nor any *Sequoia* (which is confined to the western coast region of America), nor *Ginkgo*. The maiden-hair tree, *Ginkgo biloba,* is common in cultivation in the United States, and is the sole survivor of a once abundant tribe. It is considered doubtfully indigenous in one locality in China, but

probably would be extinct, had it not been taken into cultivation long ago. During our stay on the Kudia River, we did our best to make a good collection of fossils, but the locality is not nearly so prolific as Florissant or the Roan Mountains in Colorado. Some of the best fossil insects were found by Lavrushin in the bed of the stream. On finally writing up the insects, I found I had 21 new species, including four new genera. The only Hymenopterous insect was a well-preserved wing of a leaf-cutting bee, *Megachile,* still showing the dark color with pale base, as in some living Indian forms. The Diptera consisted of six species of *Plecia,* a genus which was extremely prolific in Tertiary times, but is now represented by comparatively few forms. The Homopterous insects were fine and varied, one resembling a moth. There were also several beetles and caddis-flies, as well as their cases. The types of all these are now in the United States National Museum, and have been photographed by Dr. R. S. Bassler. The beds are of course of Tertiary age, and I think probably later than Eocene, but at present the exact age can not be determined. Unfortunately, no mammalian fossils have been found. The fossils indicate a climate which was not tropical and very likely not hotter in the summer than at present, but free from the cold winters of the modern Siberia.

We pitched our tent close to the Kudia River, but owing to the dense forest and other conditions, it was not possible to establish ourselves very close to the fossil-bed. The river is swift, clear, cold and shallow, bordered by alders almost exactly like those found fossil and poplar trees with very sweet-scented foliage, *Populus suaveolens.* In it we observed trout, which seem to represent a race of *Salvelinus malma,* originally described from Kamchatka. It is a form of this fish which is known as the Dolly Varden trout in this country. We were reminded that we were in the Palearctic region by continually hearing the voice of the cuckoo, just as in England. Some mouse-traps were brought, and close to the tent we got numbers of a white-footed mouse resembling our American *Peromyscus,* but really belonging (as Dr. G. S. Miller tells me) to *Apodemus.* We also caught a red-backed vole and a shrew. One morning, just at dawn, we heard a number of rifle-shots not far away, and on going to the village next day learned that the hunters had shot a male moose, with the horns in velvet. The animal weighed 16 poods (Russian), and had very dark fur, almost black. We were told that the largest obtained in the vicinity weighed over 20 poods. The trees in the vicinity of our camp were noticeable for their beauty and variety. In open ground were larches (*Larix dahurica*). The lilacs (*Syringa amurensis*) grew tall, with very fragrant white flowers. The various species of maple, with elegantly cut leaves, seemed characteristically Asiatic. In the

meadows, perhaps the most characteristic flower was the orange *Trollius ledebourii*, occasionally presenting a variation with yellow flowers. The scarlet *Lychnis fulgens* occurred in patches. A columbine (*Aquilegia*) with dull purplish sepals grew by the river. The species of *Sedum* (stone crop) were very large and fine. A red currant was fruiting, and the small native strawberries were found to be delicious. The flora was enough to delight any botanist, but we could not give it much attention, being too fully occupied with living and fossil insects.

The collection of recent insects which we secured was large, being especially rich in butterflies, wood-boring beetles, Cetoniid beetles and sawflies. Bees proved to be local and not very numerous. Very few moths were caught at light, the commonest being a rather small form of the well-known currant moth, *Abraxas grossulariata*, which has been used so much for genetic studies in England. Minute beetles were collected in some numbers on the tent. Some of the larger Lepidoptera (determined by Dr. Moltrecht) may be cited as illustrating the character of the fauna:

(1) A beautiful yellow *Parnasius eversmanni* was caught by Mrs. Cockerell on a hill not far from our camp, July 25. The species was new to the U. S. National Museum; it occurs in the Altai mountains, Transbiakal and Amurland, but is represented even in Alaska by a race.

(2) *Colias* proved to be surprisingly rare; I took only *C. palaeno* race *europomene*, which occurs also in the European Alps.

(3) Of the whites, *Pieris melete* was common; it is a characteristic form from the Himalayas to Japan. In Amagu Village, near the sea, I took a perfectly ordinary cabbage butterfly, *Pieris rapae*. Has it been introduced?

(4) The only swallowtail was *Papilio machaon* race *ussuriensis*, a far eastern form of the common European species. Nothing was seen of the great *P. maacki*, which is so conspicuous in the southern part of the Maritime Province. On the way back, we first saw *P. maacki* at Valentine Bay, July 29.

(5) The silver-spots (*Argynnis*) were particularly numerous and varied. *A. daphne* extends to Europe. *A. anadyomene* is a species of China, Amurland, Japan, etc. *A. selenis* was originally described from the Ural Mountains. *A. neopaphia*, taken at flowers of *Sedum*, is a race of the common European *A. paphia*. The European *A. ino* was represented by a race *amurensis* and *A. adippe* by race *xanthodippe* and a form approaching *coredippe*. Thus six species in all.

(6) The European *Melitaea athalia* was represented by a race *amurensis*.

(7) The comma-butterflies were represented by *Grapta c-album*, which occurs even in England.

(8) The handsome black and white *Limenitis helmanni* was very common at our camp. It is a species of central Asia and China. A species still more suggestive of the country to the south was *Neptis thisbe*, which I took at the fossil-diggings.

(9) I was especially pleased to take *Pyrameis indica*, though smaller and not so well colored as it occurs at Okeanskaja. This insect reappears in local races at the other extreme end of the Palearctic region, being abundant in Madeira and the Canaries.

(10) The moths included the common European *Spilosoma lubricipeda,* and a local race (*askoldensis*) of the European *Cosmotriche potatoria.*

(11) We saw a sphingid, but could not catch it. A specimen of *Pergesa askoldensis,* native of Amurland and Japan, south to Askold Island, was taken on the "Aleut" between Olga and Amagu.

It will be seen from the above that the fauna is strictly Palearctic, and consists very largely of species which extend even to the Atlantic coast, though often subspecifically different at the ends of their long range. When we later collected in the southern part of the Maritime Province, we obtained many species not observed in the vicinity of Amagu and had the impression that the fauna was decidedly different and appreciably richer. There may, however, be some fallacy here, due to the fact that the Amagu collections were not only obtained a little earlier in the year, but the season so far north was necessarily much later than near Vladivostok. Thus, for purposes of more exact comparison, some one should visit Amagu toward the end of the summer, and make extensive collections. As an illustration of the difference in season, at Okeanskaja early in July the common touch-me-not (*Impatiens*) was in full flower. By the Kudia River we found the same plant, but the first flower was not noted until July 24. This would indicate at least three weeks' difference in the seasons. We found the days very warm all over the Maritime Province, at least when the weather was fine, but the nights on the Kudia River in July were uncomfortably cold.

The "Aleut" had gone on to Sachalin Island, and was expected to return in about twelve days. As other chances of getting back to Vladivostok were quite problematical, we decided to move down to the village and take the "Aleut." Owing to the absence of any means of communication, it is impossible to say exactly when a boat will arrive; and as the vessel only remains an hour or two in the gulf, it is necessary to be ready to go on board at any time of day or night. Furthermore, there are three different landing places, and it is hard to tell which will be used in any given case. Thus we spent a rather anxious night at Shareipoff's, and early in the morning some of the young men were on the roof of the shed, looking for signs of the vessel. Eventually she did arrive, and we hastened to the shore, only to find that the lighters were coming in half a mile or more away, and we had quite a scramble to get to the proper place in time. In the confusion, a wooden box containing our plant fossils and pickled mice was left behind, and we almost gave it up for lost. Through the kindness of Mr. Shareipoff it was put on the "Aleut" when next she called at Amagu, and reached Vladivostok only the day before our departure from Siberia. We repacked most of the fossil plants and sent them overland to Petrograd, where they will be studied by Dr. Kryshtofovich. A small series we placed in the Vladivostok Museum. In Japan, it

was only by a narrow margin that we escaped losing our collections at Yokohama; so it very nearly happened that the fossil plants, supposed to be lost, were the only things saved.

The return trip to Vladivostok was uncomfortable, owing to the stormy weather. On July 29, I went ashore at Valentine Bay, and the same day Mrs. Cockerell and Lavrushin had a short time at Preobrageniya Bay. Arriving at Vladivostok, the numerous passengers were delayed for examination by the authorities; but with our "mandate" we were able to leave at once, and proceed to the hotel.

During August we worked in two localities, Okeanskaja and Kongaus. On two occasions we were guests at the summer cottage of Mme. Polevoi, wife of a well-known local geologist. Through her kindly hospitality we not only had a very enjoyable time, but greatly added to our collections. I never saw so many butterflies in one locality as at Okeanskaja. The grandest of all, both here and at Kongaus, is the dark *Papilio maackii* of Menetries, originally collected by the explorer Maack on the Amur River. Other extremely fine species, taken near the railway station, are *Apatura schrencki,* known from Amurland to Corea, and *Limenitis populi* race *ussuriensis,* a far eastern race of a well-known European species. Another swallowtail, not seen at Amagu, was *Papilio xuthus.* I took a single *Colias* in fine condition, *C. poliographus,* usually considered a race of the European *C. hyale.* The Saturniid moth *Caligula japonica* abounds in these woods, as I was informed by Dr. Moltrecht, who stated that it was introduced from Japan some years ago. I found a cocoon, but was not there at the season for the moths. I also found the very curious bright green cocoon of *Rhodinia fugax* subsp. *diana* of Oberthuer, another Saturniid moth. The nomenclatural type of this species, *R. fugax* proper, inhabits Japan. The related *R. jankowski,* which Dr. Moltrecht took at Sedanka near Vladivostok, has a brown cocoon. Both species feed on *Phellodendron,* sometimes called Chinese cork-tree; a genus of plants which, like the moths, is represented by forms in the Siberian coast region and Japan. A specimen of a remarkable genus of sawflies, *Megalodontes,* was taken.

The amount of endemism exhibited by the east Siberian biota depends largely on two factors, one the species-forming tendency of the group concerned, and the other the habits, whether volatile or sedentary. Thus at Kongaus I was delighted to find the peacock butterfly, *Vanessa io,* which used to give me so much pleasure as a child in England. It extends from one end of the Eurasian continent to the other, practically unaltered. In Bartenef's account of the dragon-flies of the genus *Sympetrum,* it appears that species found near Vladivostok extend in several cases to Europe, in one to

Japan. But Kiritshenko, discussing the bugs of the genus *Aradus*, sedentary animals which live under bark, indicates quite a series of endemic forms in Eastern Siberia.

The train which takes one to Okeanskaja follows a winding track eastward among the hills to Kongaus, a village in the vicinity of the Soochan coal mines. From Kongaus a cable-railway runs over a steep hill, bringing the coal to be shipped to Vladivostok. We found at Kongaus a comfortable inn, with extremely moderate charges, conducted by Mr. and Mrs. Mortakoff. Our meals were served on the porch, shaded by grape-vines, while geese vociferated in the yard below. The Russian word for goose, which we heard frequently, is practically the same as the English. In the garden were many flowers, and behind the house raspberries and vegetables. The potatoes were badly damaged by a coccinellid beetle of the genus *Epilachna,* closely allied to the bean-beetle of our country. We found both larvae and adults, and observed that the insect also fed on the wild *Solanum nigrum.* This beetle, if ever introduced into America, would be an extremely serious pest.

A great surprise at Kongaus was the discovery that the snail *Eulota maackii* was represented exclusively by a gigantic race (race *optima* Ckll.) the shells with a diameter of 32.5 to 36.5 mm. This was unexpected, because we had found the species uniform on the coast, from localities as distant as Okeanskaja and the Kudia River. The Kongaus race also seems to differ a little anatomically, but it is not certain that this is constant. Mr. Lavrushin found a beautiful yellowish-white mutation, without markings (form *albida*).

We were surprised at our failure to find several types of snails which are generally common in the Palearctic region. The circumpolar *Cochlicopa lubrica* turned up now and again, but not a single *Clausilia,* or Pupoid or Bulimoid form. Pilsbry has published a list of the snails of Corea, and although the northern boundary of that country is almost in sight of Okeanskaja, the molluscan fauna is extremely distinct. As there seems to be no physical barrier, it must be climatic. The complete list of genera of land molluscs we found in the Maritime Province is: *Eulota, Hygromia, Vallonia, Gonyodiscus, Polita, Euconulus, Cochlicopa, Succinea, Agriolimax.* All these except *Agriolimax* were found on the Kudia River; all except *Vallonia* and *Succinea* at Kongaus. All except the first two are genera found native in the United States. *Gonyodiscus ruderatus* (Studer) was very common. This species extends from Central Europe to the eastern coast of Asia, but in the British Islands is only found fossil. In spite of the damp climate and luxurious vegetation, it seemed for a time that there were no slugs whatever in the Maritime Province. But shortly before leaving Kongaus I

found, within the town limits, specimens which to all appearances (they have not yet been dissected) belong to the widespread *Agriolimax agrestis* and *A. laevis*. The former may have been introduced, but the latter surely is native. There is an old record of a *Philomycus* found up the coast north of Amagu, but this is an animal of warmer regions, and was doubtless introduced with Japanese or Chinese vegetables. Another apparently absent group was that of the Juliform millipedes, so common in Europe and America. We did find Polydesmids and centipedes, and also a Pseudoscorpion. Former glaciation may explain these apparent deficiencies in the fauna.

At the top of the hill beyond Kongaus there is an engine-house, for the purpose of operating the cables which haul the coal-trucks. This place is brilliantly lighted at night with electric lights, and attracts more moths than I have ever seen at light anywhere else. We also secured a number of moths at the lights of the guest-house at the bottom of the hill. Eventually the species thus obtained will be completely recorded, but it will suffice at present to mention *Notodonta torva*, which extends from Europe to Japan; *N. dembowskii*, confined to the Amur-Ussuri country and Japan; *Triphaenopsis pulcherrima*, which extends to India and China; *Plusia chryson*, found from Britain to Japan; *Lymantria aurora*, known from China, Corea, Amurland and Japan; *Cosmotriche potataria askoldensis*, a local representative of a common European species; *Paralebida femorata*, endemic in this region; *Dendrolimus pini*, found from Europe to Japan; a large goat-moth looking like the common European species, but probably referable to *Holcocerus vicarius*; *Spilosoma niveum*, a beautiful white moth with pink color on abdomen and legs, extending to China and Japan; and a form of the European tiger-moth, *Arctia caja*. At the flowers in the garden of the hotel we took the humming-bird moth of Europe, *Macroglossa stellatarum*.

Butterflies were also numerous at Kongaus, including a silver-spot we had not seen before, referred by Dr. Moltrecht to *Argynnis lysippe*, described from Japan. Lavrushin took a specimen of the mourning cloak (as called in America) or Camberwell beauty (as called in England), *Euvanessa antiopa*. He also collected a *Satyrus dryas*, a species extending from Spain to Japan.

A special feature of this country is its richness in the beautiful sphingid moths generally known as *Smerinthus*, but latterly classified by authors in several genera. Dr. Moltrecht collected no less than six species of these in and near Soochan. Three of them, *S. argus* (*planus*), *S. caecus* and *Amorpha amurensis*, feed in the larva state on poplars and willows; two, *Marumba jankowskii* and *M. maackii*, feed on lime (*Tilia*); the remaining one, *Callambulyx*

tatarinovi, feeds on elm. All these are exclusively far eastern, except the *Amorpha,* which goes as far west as Russia.

The small boys at Kongaus took a good deal of interest in our collecting and often assisted us. We were surprised to find that among these people the name "machaon" is used as a general designation for all species of *Papilio.* One day we were out in the forest not far from town, and Mrs. Cockerell and I wandered up a little trail, while Lavrushin went off to the left after a *Papilio* he had seen. I was hunting for a satyrid butterfly, new to me, which I had just seen, when we suddenly looked up and saw a tall man standing in the way. At first we thought of Lavrushin, but a second glance showed a Chinese, with a long rifle and a deerskin on his back. Looking again, we saw the heads of many more appearing above the bushes. Seriously alarmed, we called out to Lavrushin, and walked toward him. He declared we must have met some Russian hunters, but would go and see. After a while he came back, and said they were indeed Chinese bandits. They shook hands with him, asked what we were doing and said we should not be alarmed. Lavrushin exhibited net and killing-bottle and said we came from Vladivostok and worked in the museum. He discreetly avoided reference to the fact that we were Americans. Lavrushin suggested that we must not appear frightened, so we strolled down the trail, and I caught the butterfly (*Lethe epimenides* of Menetries) which I had been looking for. Presently we came upon a young girl tending her cow, and in a little while we were in the village. Subsequently we were told that the bandits, some thirty of them, had come down to impose a levy of 600 roubles ($300) on the Chinese merchants of the town. The night after we saw them they all slept in a Chinese house only two doors from our inn. It seemed quite possible that they might decide to carry us off if they learned that we were Americans; and as the weather was by this time very wet and I had developed a severe case of bronchitis, we did not at all relish the prospect. A Japanese friend of ours, Mr. Noda, of Vladivostok, was thus captured not very long ago, and as it was in an out-of-the-way place it took about two months before he could get his ransom and his liberty. We were told that although these bandits had been known to kill a solitary hunter for the sake of his gun, they very rarely molested Russians. The Russian young men are good shots and used to the woods (as Kolchak found during the civil war), and their vengeance would be something to be afraid of. The trails are few, and if men leave them and go across country they can not travel fast. Also, as we ourselves found, it is usually easy to follow in the tracks of a traveller, owing to the large numbers of plants with the under sides of the leaves conspicuously

pale, these showing more or less after disturbance. Owing to the vast extent of unoccupied country, and the nearness of the Manchurian border, the bandit problem is not easily dealt with, but the government is doing what it can. We heard that some of those we saw were captured soon after we left Kongaus. These bandits do not pilfer, and it is almost true to say that they behave as decently as they can, consistently with their illegal and irregular mode of getting a living. Thus we were told of a case of a young Russian student who met a party of them when out in the woods. They demanded his pistol, but he said he was poor, and it had cost him a lot of money, and he could not afford to part with it. "Very well," said they, "we will pay you." They gave him some money on the spot and promised more when it could be procured. Presumably he never saw the balance, but robbers in other countries would not usually recognize any obligation to pay.

Returning to Vladivostok, we began making arrangements to leave. This proved to be no simple matter, and it may be worth while to recite the necessary operations for the instruction of future travelers. We were living in the building of the Geological Committee, and the first step was to get registered with the police as resident there. This having been done, we could apply for a permit to leave the place, and this we secured. The next step was to visit the office of the Political Government, where we showed our papers to a young woman who looked weary with all the routine. She at once put her finger on my passport and remarked that we had been in the country more than a month. Quite so, but what of it? Well, there had been passed, since we arrived, a law or regulation requiring all who remained more than a month to get a Russian passport. This was an appalling prospect, involving I know not what red tape and delay. So the young woman took us and the passport to the office of the head of the division, who proved to be a very young-looking man reading a newspaper. She thrust the passport before him, and he looked at it out of the corner of his eye, and went on reading. We wondered at his apparent rudeness, but later realized that he perceived the dilemma and, not wishing to hold us up, simply refused to pay any attention. So the distracted young woman went back to her office with us, and allowed us to proceed. We must, however, pay six roubles gold (three dollars) for a permit to leave, and this must be done at the treasury, about half a mile away. Arriving at the treasury, we presented our authorization to an official, who gave us a paper permitting us to pay the cashier. But the office hours are short, and there was a long line of people waiting to see the cashier, so we could do no more that day. Next morning Lavrushin was at the door when the

office opened and managed to get the six roubles paid. Then we had to wait more than an hour to get a paper from still another official, stating that payment had been made. With this, we returned to the office of the Political Government, and the third day thereafter received our official permit to go. But even this was not all, for we had to get our collections out. It was necessary to get a document from the Department of Education, and another from the Department of Commerce, declaring that these offices did not want our collections, which they had not seen. This accomplished, the customs official hardly looked at our things, and we finally boarded the "Hozan Maru" on August 22; glad to start homeward, but sorry to say good-bye to the many friends we had made in Siberia.

I wrote in a letter at the time: "As to the collections, it will of course be great good fortune if all comes through without breakage or mold—perhaps too much to expect, but we are certainly through the worst dangers, and there is a good prospect for success." Little did I realize what was in store for us at Yokohama, but nevertheless we did get through, practically without loss or damage. Looking back at it all, it was rather a rash undertaking, especially for people beyond the plasticity of youth. We were often weary or uncomfortable, and on more than one occasion not far from disaster. Yet we brought back precious memories as well as valuable collections, and eventually we hope it will appear that a distinct contribution has been made to Siberian natural history. It may be worth while to have demonstrated that something can be done with very moderate resources, in a limited time, without any backing from wealthy organizations. It certainly was worth while to come to know and respect the Russian people, and share their hope that after years of confusion and misunderstanding there will eventually arise a renovated nation which may teach the rest of the world some things it needs to know.

THE BORING HABITS OF THE SHIPWORM

By Dr. ROBERT CUNNINGHAM MILLER

UNIVERSITY OF CALIFORNIA

THE method by which the smooth-walled, perfectly rounded burrows of the shipworm are excavated in wood has excited the curiosity of man since an early time. In the first century A. D. the Roman naturalist Pliny the Elder remarked upon it. "What teeth (Nature) has given the teredo," he exclaimed, "even for perforating oak! . . . And also she has made from wood its principal nourishment."[1]

This conjecture as to the purpose of the denticles on the shell appears to have gone unchallenged until 1733, when the Dutch investigator Sellius[2] objected that the shell of *Teredo* does not appear adequate to the task of boring, especially in the harder woods. He believed the boring to be accomplished by a kind of suction with the foot, aided by the action of the water which is being continually taken into and forced out of the burrow.

The opinion of Sellius precipitated a discussion which has been carried on intermittently for nearly two hundred years. Certain experimental difficulties having interfered with direct observations of the shipworm in action, the debate has been more or less academic, the nature of the premises and the vigor of the discussion suggesting analogies with a well-known medieval controversy regarding the number of teeth of the horse.

While a majority of writers have favored the view that boring is carried on by movements of the shell, not a few have insisted that the burrows are excavated by a slow but continuous wearing away of the wood by friction and suction with the foot. Still a third group has maintained that a chemical action of some sort is involved in the boring process.

The theory of boring by means of the shell rests largely on morphological grounds. The shell of *Teredo* has been reduced, relative to the size of the animal, until it covers only a small portion of the anterior part of the body. It is a subglobular structure, gaping in front for the protrusion of the foot, and behind for the protrusion of the long, slender body. It consists of two valves, which are capable of rocking back and forth on specialized dorsal and ventral knobs, so that the anterior and posterior adductor muscles oppose

[1] Caii Plinii Secundi Historia Naturalis, Book XI, Chap. 1.

[2] Godofredi Sellii Historia Naturalis Teredinis seu Xylophagi Marini, pp. 78 ff. Trajecti ad Rhenum, 1733.

each other in action. The anterior portions of the valves are equipped with sharply denticulated ridges, the projections of which are directed outward and backward. The structure of the shell, coupled with the fact that the posterior adductor muscle is somewhat more than thirty times as large by volume as the anterior adductor, strongly suggests that boring is accomplished by movements of the valves, repeated contractions of the large posterior muscle causing their forward edges to spread apart and rasp the wood.

To this it has been objected by advocates of the theory of boring by means of the foot that the shell is inadequate to the task of boring, that it does not show signs of wear as would be expected if its function were that of rasping wood, and that the walls of the burrow of *Teredo* are too smoothly polished to have been rasped mechanically. It has been further pointed out that certain forms, such as *Patella,* are able to make depressions in rocks by means of the foot.

Proponents of the theory of boring by chemical means have little to offer in support of their views except a presumed inadequacy of both shell and foot to accomplish the observed result. Nevertheless, this theory had the backing of such authorities as Gray, Deshayes and De Quatrefages, all of whom during the nineteenth century made noteworthy contributions to the knowledge of marine borers.[3]

In order to determine if possible by direct observation which of the foregoing suppositions is correct, the writer recently tried the experiment of carefully opening the burrow of a teredo near the anterior end and sealing over the opening with a glass cover-slip, thus making a small window in the burrow, through which the movements of the occupant could be observed with the aid of a binocular microscope and a narrow shaft of light. Most of the animals disturbed in this fashion would retract about a third of the length of the burrow, so that they were entirely out of sight from the window, and after a few days' quiescence they would bore off in another direction. But after a number of repetitions the experiment finally proved successful. One specimen was found which carried on boring operations directly in view of the small glass window, and the process was observed in considerable detail.

The boring is accomplished by rasping with the valves, which are held in position by the combined action of the foot, attached to one wall of the burrow, and the dorsal fold of the mantle, distended by turgor, pushing against the opposite wall. The typical boring position is seen in Fig. 1a.

[3] Readers who desire a fuller account of the various theories of boring are referred to Miller: "The boring mechanism of *Teredo,*" Univ. Calif. Publ. Zool., vol. 26, pp. 41–80. 1924.

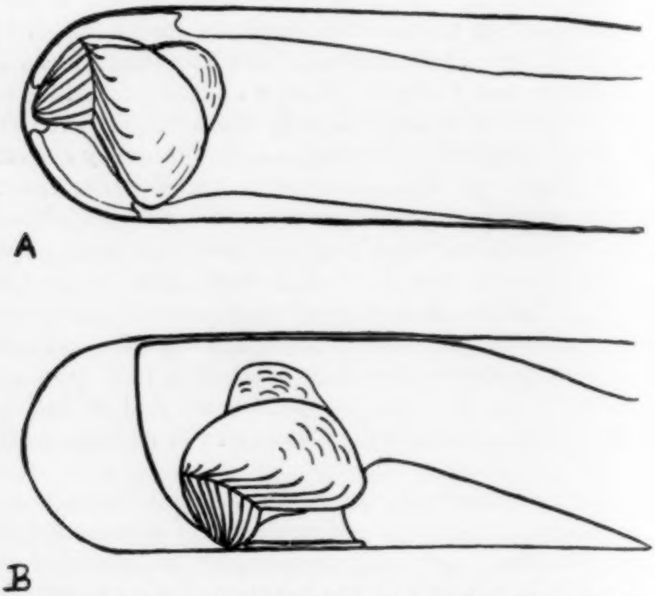


FIG. 1. *Teredo*. a. Typical boring position. b. Boring position when beginning a side passage at a right angle to the former course of the burrow.

The effective stroke of the valves is the outward and backward one, as had already been assumed from the direction of the points of the denticles on the shell, and from the extraordinary development of the posterior adductor muscle. At each stroke of the valves the foot takes a new hold. As the backward stroke of the valves is completed, the foot is relaxed and its margins spread out so far that they overlap the edges of the shell. Then, by a sudden contraction, the margins of this structure are drawn in and the valves brought forward into position for a new stroke. Then follows the slow, labored contraction of the large posterior adductor, causing the forward edges of the valves to spread apart and rasp tne wood on their outward thrust. That the valves do actively scrape the wood on this stroke is indicated by the fact they were observed frequently to slip, the backward margins being drawn together with a jerk instead of the usual slow, steady pull. The boring movements occurred rhythmically, from 8 to 12 times a minute.

The anterior tip of the burrow is mined out by the anterior lobe of the shell; the movement of the shell is necessarily in a direction longitudinal to the ridges of this area, so that their serrate edges act upon the wood as so many small saws. The serrations on the ridges of the anterior area are extremely fine, as compared with the

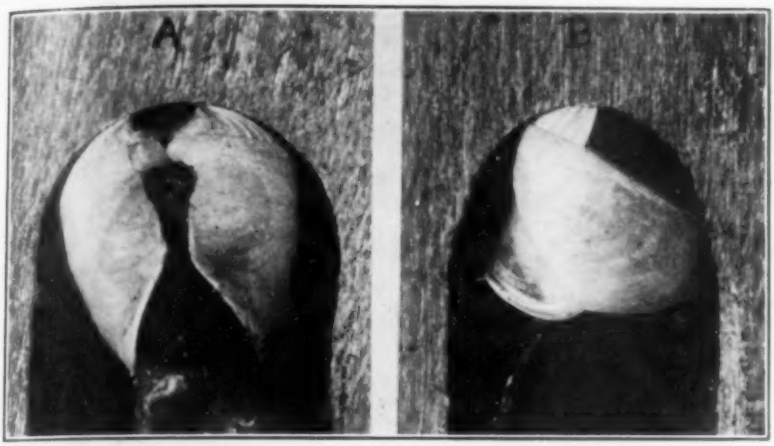


FIG. 2. Shell of *Teredo navalis* mounted in position at end of burrow, x 10. a. Dorsal view, b. Lateral view.

denticulations of the anterior portion of the median lobe of the shell, and hence better fitted to act as the advance boring edges. Also the shape and position of the anterior lobe especially adapt it to working in the extreme tip of the burrow (see Fig. 2). The marks of the work of the anterior lobe of the shell are often plainly evident on the wood (Fig. 3).

While the ridges of the anterior lobe are working saw-fashion in the tip of the burrow, the coarser, wedge-shaped teeth of the anterior portion of the median lobe of the shell are at the same time working rasp-like, enlarging the diameter of the burrow and advancing the peripheral portion of its cupped extremity. Thus, while the tools might be compared to saw and rasp, their work is in effect that of drill and reamer.

The disposal of the rasped-off particles of wood it was not possible to observe, because of their minute size. There is, however, every reason to believe that they are swept by the cilia of the periphery of the foot into the range of the cilia of the esophagus. Apparently all the rasped-off wood passes through the digestive tract, where a considerable portion of it is utilized as food by the animal,[4] as Pliny had further surmised.

The position assumed by *Teredo* in boring off at a right angle to its former direction of progress is seen in Fig. 1b. One would hardly have supposed that such an awkward position is assumed by the animal in changing the course of its burrow, were this not

[4] *Cf.* Dore and Miller: "The digestion of wood by *Teredo navalis*," Univ. Calif. Publ. Zool., vol. 22, pp. 383–400, 1923.

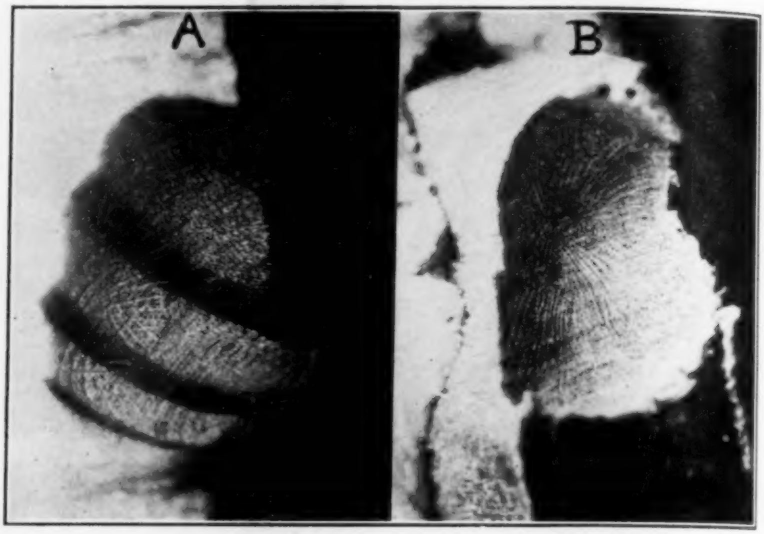


FIG. 3. Cupped extremity of a burrow showing marks of the work of the shell, x 10. a. *Teredo navalis*. b. *Teredo diegensis*.

actually a matter of observation. Apparently the valves function without difficulty under such circumstances. This explains how *Teredo* is able to make the abrupt changes in the course of its burrow which are so often found, especially in heavily riddled piling, where such changes of direction are necessary in order to avoid breaking through into neighboring burrows.

The commonly made statement that one *Teredo* will never bore into or cross the burrow of another is not, strictly speaking, true. Occasional instances have been found in which one burrow passed directly through another. Such cases are rare, however, and it is probable that the first animal was dead before the second entered its burrow, as otherwise it would doubtless have been able to protect itself by a thickened wall of nacre. In heavily riddled timbers the teredos will sometimes adopt unusual expedients, such as to cross a crack of considerable magnitude in order to find new wood to attack. One instance was observed in an aquarium where a teredo had bored completely through a piece of wood, so that its shell and the anterior part of the body protruded into the water. This animal was doubtless abnormal.

The foot appeared, from observation, to be an organ of sense and a means of limited locomotion about the narrow confines of the burrow. The animal under observation through the window made in the burrow was seen to turn from left to right and back again a number of times, as though exploring the wall of the burrow with

the foot, before it made any boring movements. Probably thus in some way *Teredo* becomes aware of neighboring burrows, so as to turn aside and avoid them. In executing these turning movements, the foot several times passed directly across the glass, so that the manner in which it functioned could be well studied. The organ was first flattened against the surface of the glass, and its margins spread out so that they extended beyond the edges of the shell. Then, apparently by contraction of the retractor muscles of the foot, the margins were rather suddenly drawn in and the central disc of the foot slightly cupped, obviously constituting a sucker. After each contraction the foot sought a new attachment, moving laterally about 0.5 mm and hitching the shell along to a new position.

During the course of this exploration of the walls of the burrow, the animal was observed to turn about its long axis 260 degrees in one direction and 220 degrees in the other, or a total of 480 degrees. The body was obviously twisted, owing to the animal's being attached to the burrow at the posterior end, but this twisting appeared to occasion it no inconvenience. Thus is solved the problem of how the shell can be brought into the various positions necessary for excavating the regularly cupped, perfectly rounded burrow. It was obvious from the markings shown in Fig. 3 that the shell must have been rotated by slow stages through at least 180 degrees in each direction in order to produce the striations radiating in all directions.

The further possibility that *Teredo* might facilitate its boring by the use of some secretion which has a solvent action on certain constituents of the wood was also investigated. It would seem that the action of such a substance, if it occurs, should spread at least for a limited distance through the cells of the wood at the extremity of the burrow. The tracheids of Douglas fir are from 1 to 3 mm in length, and it is hardly conceivable that a secretion applied to one end of a tracheid should not spread through its entire length. Probing in the extremity of the burrow with a needle, however, did not reveal any area of softened wood, as would be expected on this hypothesis. Micro-staining with hematoxylin, which is a selective stain for cellulose, did not reveal any diminution in the cellulose content of the wood at the end of the burrow. It was further attempted to compare quantitatively the composition of shavings of wood immediately adjacent to the burrows of *Teredo* with that of shavings from sound portions of the same timber. An analysis of these samples did not indicate that any substances had been removed by the enzymes of the borer from the wood forming the wall of the burrow.

While the writer does not consider that the possibility of the use of a glandular secretion to facilitate boring is definitely disproved by these experiments, the evidence strongly indicates that boring is performed entirely by mechanical rasping of the valves on wood that has been to some extent softened and macerated by the presence of water in the burrow.

The experiment was tried of rasping the surface of a piece of Douglas fir wood under water with a medium-sized teredo shell held between the thumb and forefinger. By this method a depression 6 mm in diameter and 1.2 mm deep was made in 30 minutes, at the end of which time the denticles of the shell, examined under the microscope, showed not the least trace of wear. A similar attempt to rasp dry wood, however, resulted in the speedy destruction of the shell. Thus it appears that the action of water alone is sufficient to greatly soften the wood and accordingly facilitate boring. The assumption of a chemical action on the wood by some unknown secretion produced by the borers is quite unnecessary.

It is not the intention of the writer to defend the somewhat moth-eaten scientific reputation of the blandly uncritical Pliny, but in this instance at least he appears to have hit upon the right conjecture, both as regards the mechanism of boring and the utilization of the wood as food. It was perhaps the very simplicity of the actual method of boring of the shipworm which led so many later investigators to overlook it in a search for some more obscure explanation.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON
SCIENCE SERVICE, WASHINGTON

GASES HEAVIER THAN LEAD

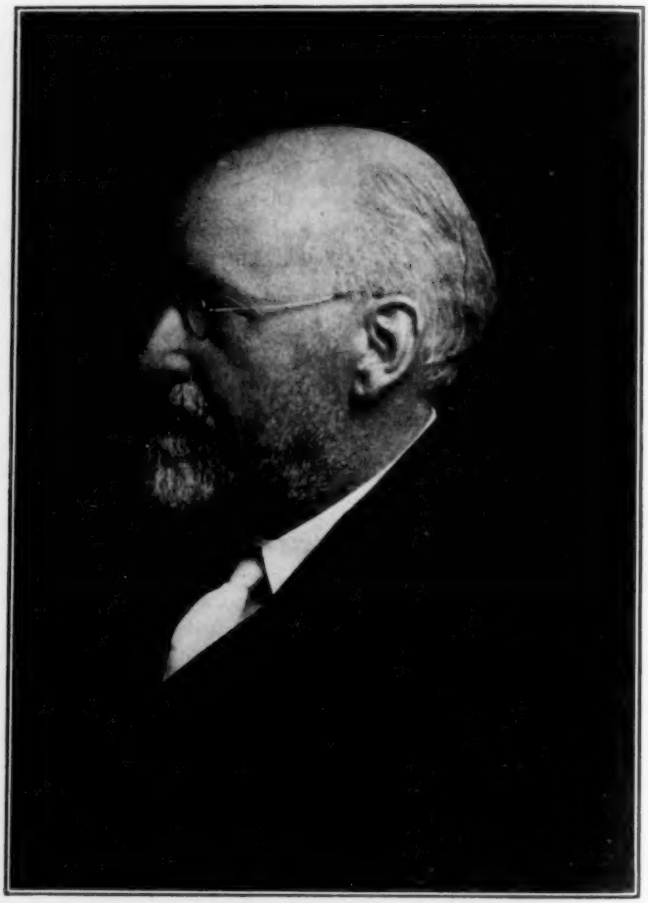
PROFESSOR A. S. EDDINGTON, of Cambridge, can spring more sensations in a half-hour talk than any other sober-minded scientist I ever heard. He broke the record at the Toronto meeting of the British Association for the Advancement of Science when he expounded his new theory of the constitution and evolution of the stars. An old-fashioned physicist, if any such were in the lecture room, must have been shocked to hear him talk so calmly of gases more than fifty times heavier than platinum, of temperatures over twenty million degrees centigrade, of light waves that are lengthened by gravitation, of chemical elements losing their identity, of stars puffed out by the internal pressure of X-rays, of dwarf stars that are giants at heart, of gases made up of mere electrons and nuclei, of matter converted into energy and of stars that are dissolving into light.

If these were mere speculations, such as some astronomers indulge in, Camille Flammarion for instance, nobody need mind, but Professor Eddington insists and persists in proving his points. He began by working out the mathematical theory of star formation on the assumption that its substance behaves like a perfect gas. Then on plotting the observational data of stars of all sorts these were found to fit closely to his theoretical curve, even our own sun which has a density one and a third times greater than water. From this he concludes that stars in general obey the laws of perfect gases, regardless of their density, and that their luminosity depends mainly upon their mass, the density making comparatively little difference.

Some stars seem to have a density heavier than platinum. For instance, the faint companion of Sirius has a mass eight tenths as much as the sun, yet its size, as judged by its light, must be so small that its density should be fifty thousand times that of water. Whether its mass is really so great may be determined by observing the Einstein shift in its spectrum and this is now being tested at the Mt. Wilson Observatory.

The new theory conflicts with the theory advanced by Professor H. N. Russell, of Princeton, and now commonly held, that stars start out in life as red giants of extreme tenuity, that heat develops as they contract, and that they get hotter as they lose heat, until they become white hot and then gradually cool down to red heat again. Professor Russell, in spite of the fact that a hard blow had been dealt at the theory which had given him an international reputation, was the first to congratulate Professor Eddington on his achievement. "I take off my hat to him," he said, "for this is the second time he has deduced from mathematical principles what ought to have been obvious, but was not perceived before."

A possible agreement between the rival theories may be brought about by invoking Einstein's idea that matter may be converted into energy and radiated off into space. Professor Eddington says: "It is possible that a star may gradually diminish in mass during its evolution. This would



SIR WILLIAM BAYLISS

The distinguished British physiologist, professor of physiology at University College, London, noted for his work on the circulation and a number of physico-chemical problems in physiology, who died on August 27.

happen if it obtains its energy of radiation by annihilating electrons and protons, thus burning itself away."

According to Professor Eddington's theory, stars continue to get hotter as they shrink until the central temperature is over ten million degrees Centigrade. At this heat the atom of the heavier elements would be stripped of its outer electrons and the atom of the lighter elements, like carbon and oxygen, would be reduced to the bare nucleus. The atoms in the stars would then have only about one hundred thousandth of the bulk of ordinary atoms, and such a gas could be compressed a hundred thousand times further than the gases we deal with on earth before the atoms begin to get crowded. In such a state all the stellar gases must have about the same molecular weight, 2.1, whatever may be the elements that compose them.

When I was young, astronomers used to try to scare us by telling us that the sun and stars were slowly cooling down and at length the universe would be left all dark and cold. That did not worry us enough, so now they have changed their tactics and prophesy a time when the elements shall melt with a fervent heat and the sun shall be no more. This sounds more alarming, for it would be worse for the human race to be roasted alive than frozen to death, and the idea that the solid ground may ultimately be dissipated into radiant energy and go rambling around a four-dimensional continuum forever gives one a new kind of shiver.

A GREEN-HEADED IDEA

As I was passing a florist's shop-window not long ago I saw a little image of a man's head in porous brown pottery, and on the top of it instead of hair there was a fine growth of grass, rising straight and thick from the forehead like Senator La Follette's hair. It occurred to me at once that this was a bright idea. For what good is hair anyhow? You can't pasture sheep on it, and you have to pay a barber to run a lawn mower over it and then he does not allow you anything for the crop. Now if we could grow grass instead it would cover the head quite as completely, and look as well—after we got used to the color—and, what further appealed to me, when the sod got thin the surface could be reseeded.

As I walked on the idea sank deeper into my brain. Would it not be possible that the grass growing on one's head might send down through its roots a constant supply of proteins, fats, carbohydrates and vitamins in the proper assortment so as to do away with the necessity of food? For it has always seemed to me a humiliating necessity, unworthy the dignity of man, that he should have to be dependent upon the plants for the fixation of solar energy that supplied his motive power. Just for lack of a little chlorophyl must man remain forever a parasite on plants? If man only had a head as good as a cabbage, he could accomplish the process of photosynthesis for himself.

Or, if man could not acquire the necessary chlorophyl, could he not form a close combination with some sort of plant life that possessed this power, as by farming out on shares any waste land he might have on his head? On looking up the matter I found, as I often do, that my idea was not so original as I supposed. I had, in fact, been anticipated by a million years or so, for certain sea creatures and land fungi, which, like man, were devoid of chlorophyl, had incorporated green vegetation which fed them the solar energy that they could not secure for themselves. The

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Who is now returning on the schooner *Bowdoin* from his expedition in the Arctic regions.

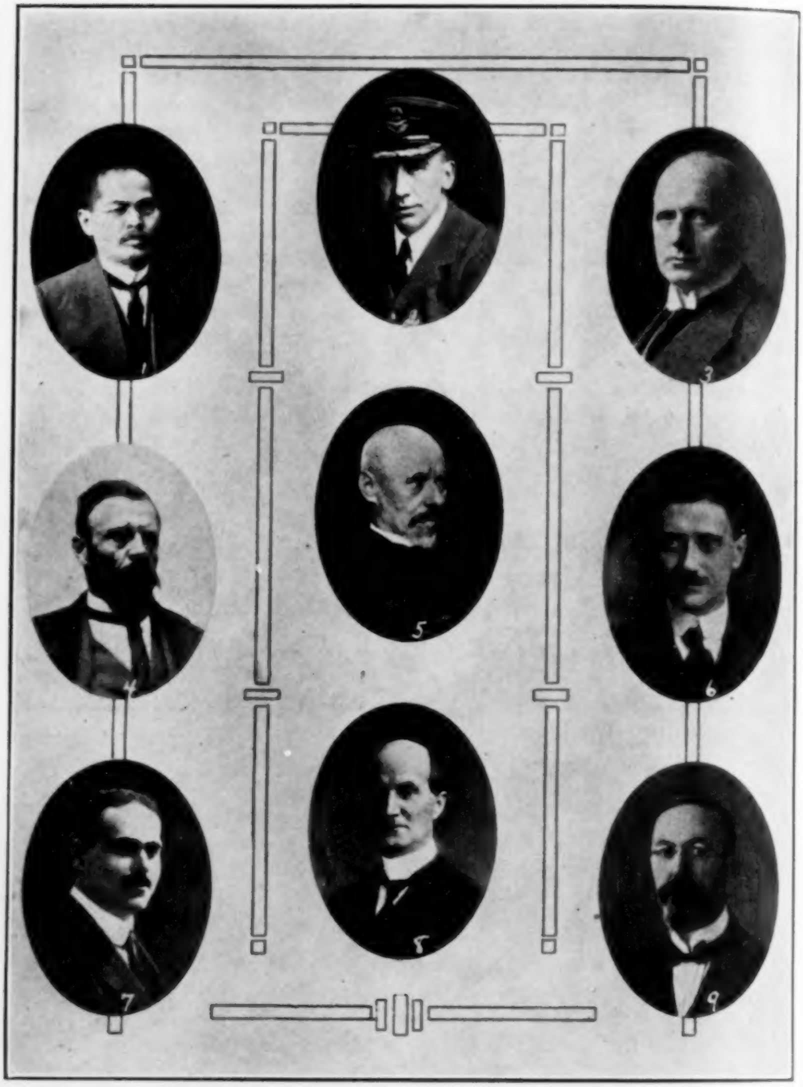
lichens have carried on such a partnership between plant and fungi for untold ages. The botanists call it "symbiosis," probably to avoid the commercial taint of the word "partnership."

But even though I had been beaten to it by the lichen, it did not appear that anybody had got a patent on symbiosis as applied to man. So I set about figuring out the acreage necessary for a home-grown dietary. I drew the outline of my hat band on a sheet of paper and laid it off in centimeter squares with a ruler. The area added up to 260 square centimeters. I sent this figure to a friend of mine who knows more about the value of solar radiation than anybody else, and asked him how many hours I would have to sit out in the sun to receive enough energy to equal what I now take in as food. My dietary I figured as roughly 3,000 calories a day on the average, including a rather hearty Sunday dinner.

He wrote back that I should have to have more of a swelled head than I had already to carry out the scheme. I did not understand what he meant at first, but on going over his figures I saw the difficulty. One square centimeter of the earth's surface at the equator receives from the sun, or would receive if there were no clouds or atmosphere, .00194 calories a minute. At the latitude of Washington and sea level, a square centimeter receives in the course of a year only about 152 calories. Accordingly the solar expert to whom I referred the question concludes: "For your requirements of approximately a million calories a year, the diameter of your head would have to be increased between five and six fold, in order to receive enough energy from the sun to sustain your mental and physical operations, and you would have to sit out in the sun all day long, every day in the year. These figures take account of the losses in the atmosphere and the obliquity of the rays, so you could hold your head up straight and not have to turn it around like a sunflower, as you suggest."

I do not easily give up an idea, so I measured my back and calculated its area, only to find that this, however well sodded, would not be a third large enough. Worse still I found that the green leaves are shockingly inefficient transformers of energy. They store up in the form of combustible or edible products only about one per cent. of the radiant energy they get from the sunshine. It would then take some three hundred mossbacks, working full time, to provide my necessary nutriment.

So I have been forced to admit that my scheme is impracticable, at least in its original form, but my figuring has the stronger confirmed my belief that some way might be found to make use of solar radiation for human purposes, without wasting more than ninety-nine per cent. of it, as is done by employing plants as intermediaries. An area of twenty square feet in latitude 38 degrees and at sea level, receives energy enough through the year, counting all the days as sunny, to give one horsepower continuously. If the weather is half cloudy forty square feet would amount to one horse power. This means that taking the country through each acre of land is getting more than a thousand horse power, and each square mile more than a half a million horse power of free energy from the sun, and yet we make no use of it except such infinitesimal fraction as may be converted into food or fuel by vegetation, or may raise water to the clouds to come down as rain and perchance to be caught by a water-mill, or may stir up the atmosphere to be used in running a few scattered windmills. It does seem to me that we might use a little more of this wasted wealth than we do. But the problem is too big for my head to solve.



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A TABLE TRICK AND WHAT IT TEACHES

When that stage in the dinner comes when everything has been cleared from the cloth except coffee cups and ash trays, and when those who do not smoke are toying with the extra lumps of sugar instead, then some one may remark: "It's funny that you can't set suger on fire with a match, isn't it?"

Everybody agrees that it is funny, so funny that they do not believe it. Sugar is food, all foods are combustible if they are not too wet. Those who know more about it are more positive; sugar is a carbohydrate and thus belongs to the same family as paper and wood. Why shouldn't it burn?

So they try it, setting up the domino on the saucer and holding a match to the edge or corner of it. But all they can get is a dull smoulder and a bad smell. The sugar softens, blackens but refuses to inflame.

They turn to the man who propounded the paradox and ask: "How do you explain it? Why can't you set sugar on fire?"

He takes his cigar from his mouth and remarks with a quizzical smile, "I can. What I said was that it is funny that you can't."

This starts a chorus of incredulity. "Let's see you," demand the skeptical. "Bet you can't," assert the mercenary-minded, who never take an interest in a conflict of opinion unless they have money at stake.

He accepts the challenge and perhaps the wagers. He sets up his lump of sugar, touches it with a match and it flames up promptly and goes on burning with a sooty flame.

Only the most observant of the tableful have noticed that he had first clumsily dropped the lump of sugar in the ash tray or with apparent inadvertence had touched it with the tip of his cigar. This is the secret of it, that a slight smear of ash from cigar or cigaret will so lower the ignition point of sugar that the heat of a match is sufficient to set it afire. Yet the ash does not act as kindling. It is not combustible. It has already been burned. And sugar alone will not inflame in the heat of an alcohol lamp, a gas jet or even the powerful Bunsen burner. It merely melts and chars. It may be consumed but does not burn freely.

This curious reaction has been thoroughly studied by Hedvall who had tried all sorts of chemicals on sugar in a Bunsen flame to find out what it is that causes the effect. The carbonates of sodium and potassium, such as exist in cigar ash, were among the most effective in lowering the temperature of combustion of sugar. Various other oxides of alkalies or alkaline earths, such as lime, will work the same. Zinc oxide is the best of all. The sugar touched by this will flame and crackle and burn completely.

Common salt and the sulfates of iron and copper will cause the sugar to burn, but only in part, leaving a black porous residue. Silica and the oxides of the heavy metals have no effect.

This simple experiment is a good example of what the chemist calls "catalysis." He does not know what it is but he has learned how to use it. It has been found in many cases that the presence of a minute amount of an inert substance, like the ash here, will greatly accelerate a reaction and yet is not used up in the process. A finely divided metal often acts as a catalyst. Platinum is the best, but being so expensive some cheaper metal, such as nickel or iron, is more commonly employed. It is by means of such a catalyst that sulfuric acid is now made; that the nitrogen of the air is fixed for use as fertilizer in the form of ammonia or nitrates; that cottonseed oil is combined with hydrogen to form a solid fat. The use of catalysts is adding millions annually to the wealth of the world, yet in most cases the manner of their action is not understood.

THE INTERNATIONAL CRITICAL TABLES

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The work of preparing the data for the International Critical Tables is now actively under way. The material is being collected and critically evaluated by approximately 300 competent experts distributed among the following countries: United States, Canada, Great Britain, Belgium, France, Italy, Austria, Germany, Denmark, Switzerland, Holland, Australia and Japan.

The program covers all available information of value concerning all the properties and numerical characteristics of (a) pure substances, (b) physico-chemical systems of definite composition, (c) many industrial materials, (d) many natural materials, and (e) selected data for selected natural bodies or systems, such as the earth and its main physical subdivisions, the solar and stellar systems, and certain biological organisms, including man. Publications of the world in all languages will be combed for data and much unpublished information is also being collected. In addition to the stupendous scope of the tables, hitherto unapproached by any similar publication, the volumes will contain many novel features of arrangement. Thus, for example, not only will it be possible to find readily all the properties of a given substance or material but it will also be possible in many cases to ascertain readily what substance or material of a given kind has a maximum, a minimum, or a given value for any given property. This feature will be of great assistance in identifying a substance by means of its properties or in selecting a substance or material on the basis of a given property or combination of properties. The main descriptive material and the very complex index to the tables will be in four languages, English, French, German and Italian.

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